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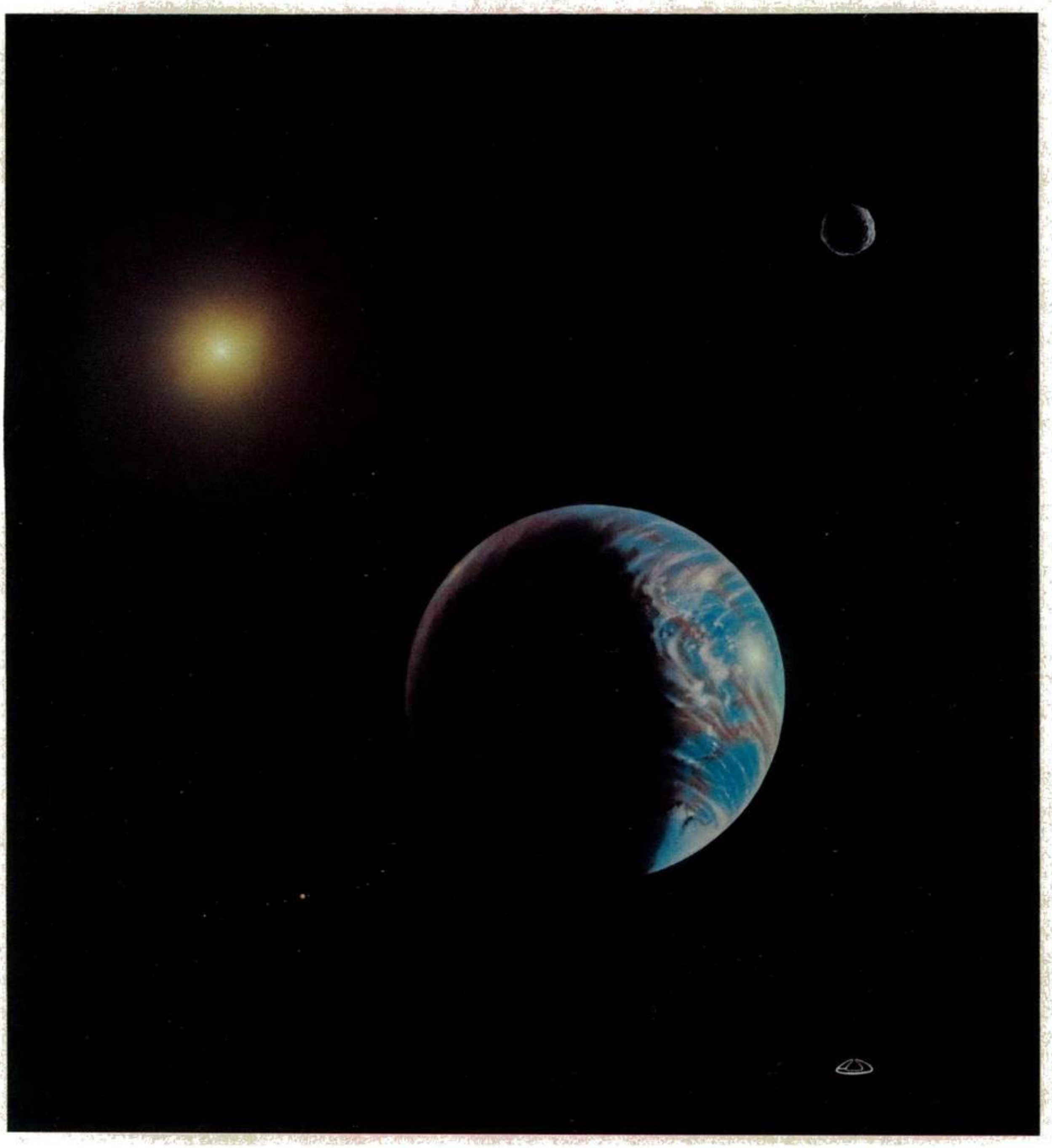

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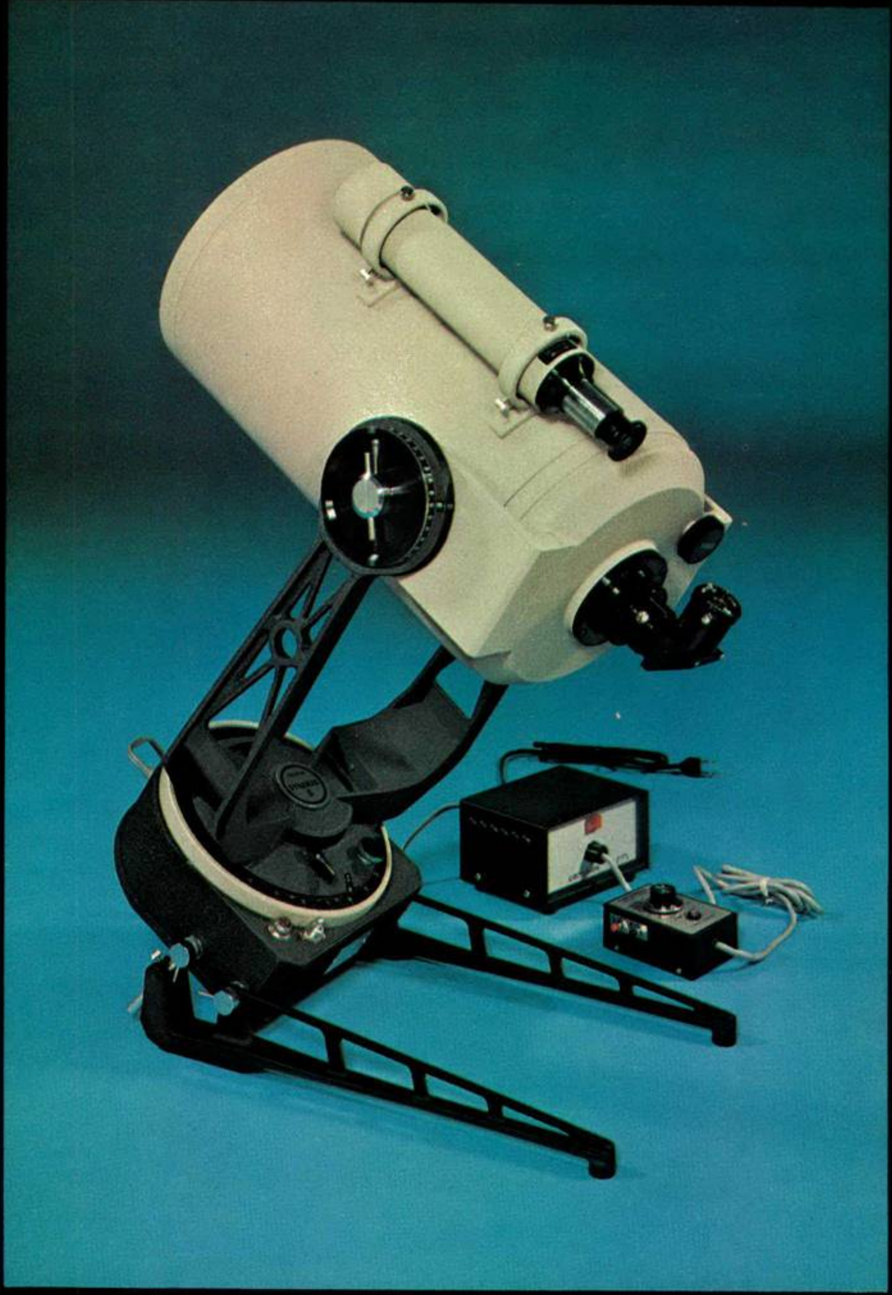

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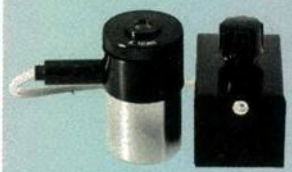

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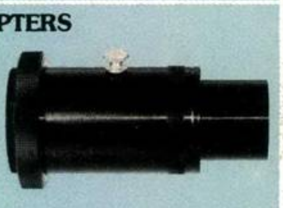

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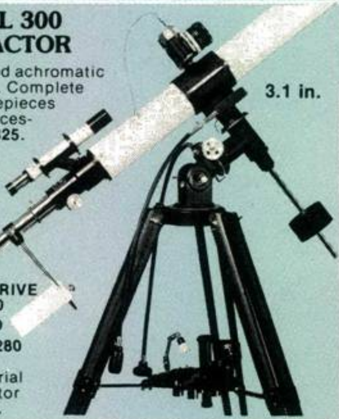

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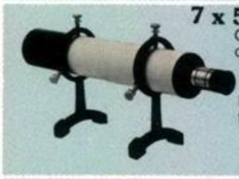

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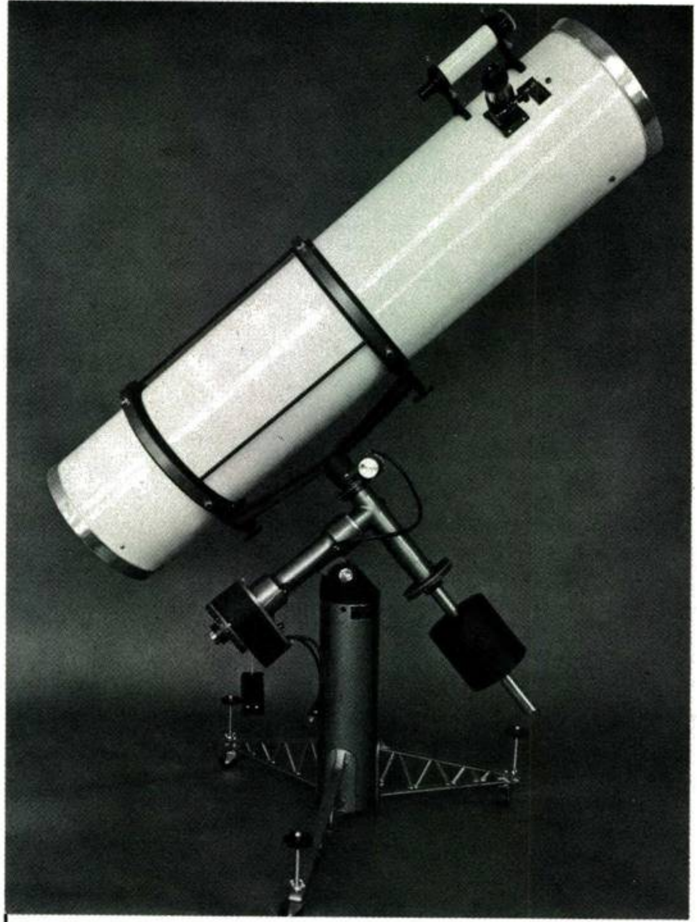

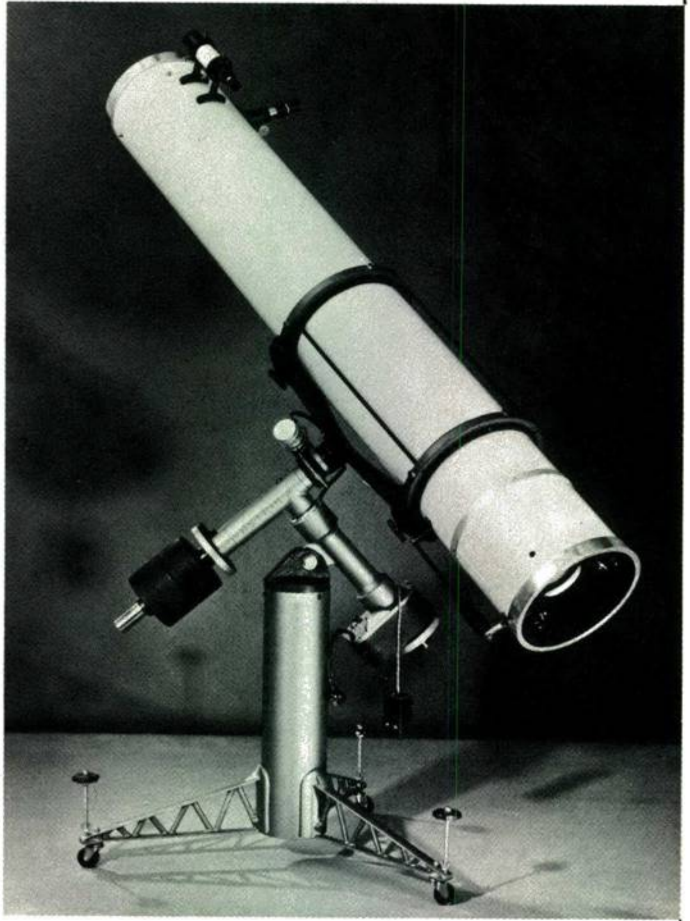

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Cover

A planet with the size and mass of Earth orbits one component of a widely separated binary. Visible in the background is another member of this hypothetical planetary system: a gas giant with its own family of satellites. If a giant planet in such a system is massive enough — Jupiter sized or larger — it may perturb the star sufficiently to produce a wobble in the star's proper motion perceptible to astrometrists on Earth. It is impossible for astrometrists using current techniques to detect small, solid bodies like the one depicted here. But the tentative discovery of unseen bodies around a few nearby stars may be the first step toward positive identification of extrasolar planetary systems. Artwork by Adolf Schaller.

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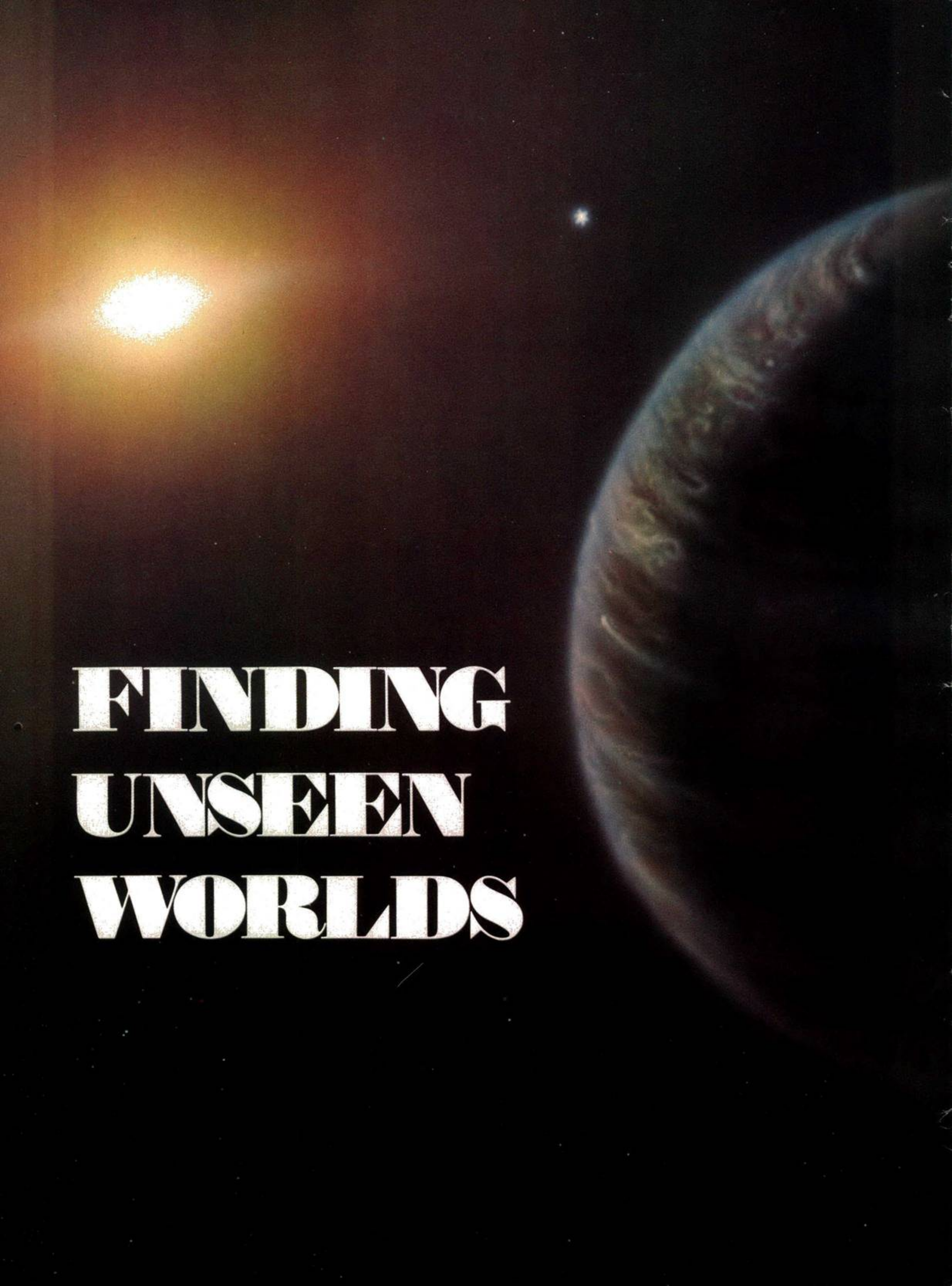
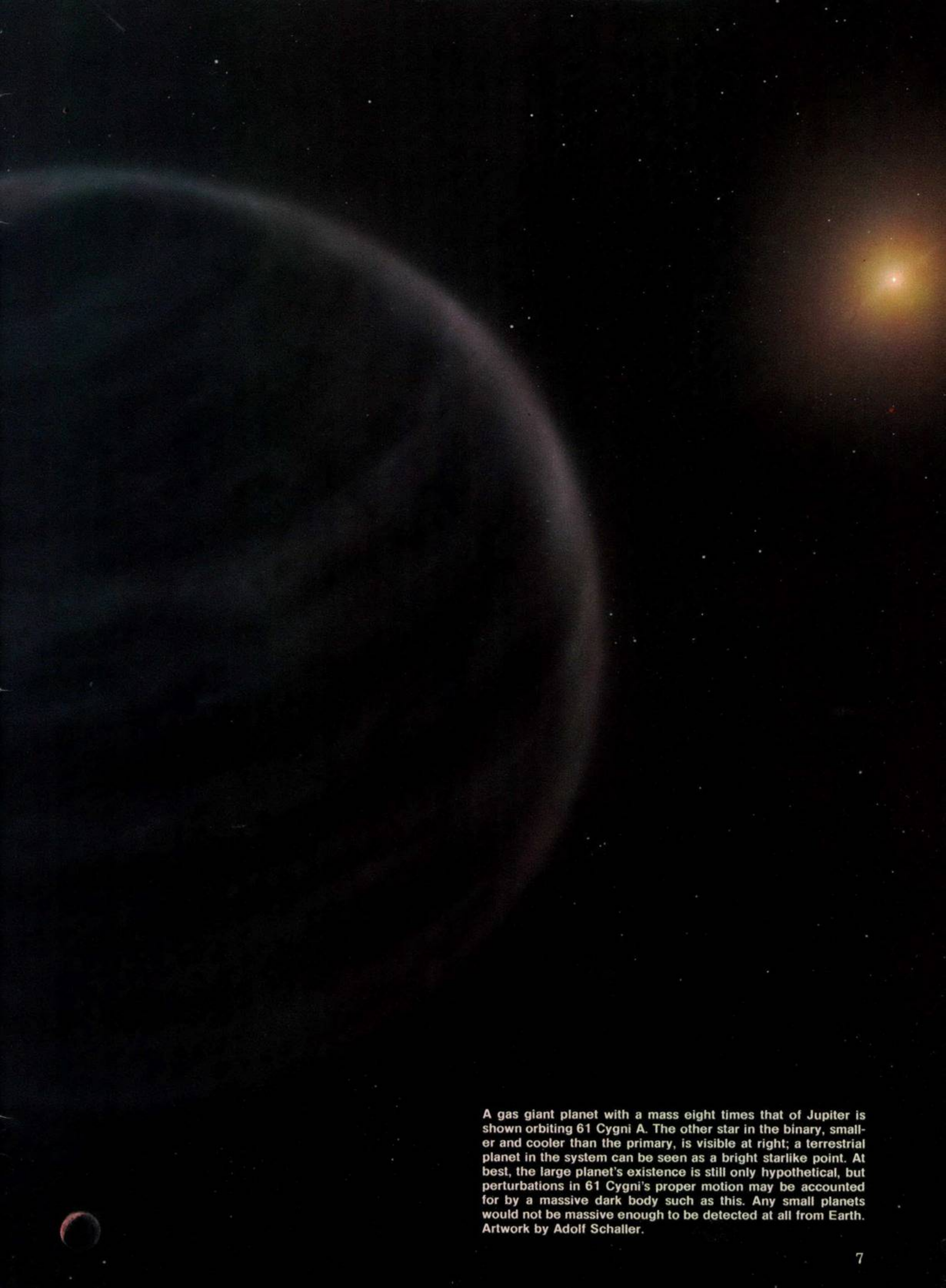


FINDING UNSEEN WORLDS



A gas giant planet with a mass eight times that of Jupiter is shown orbiting 61 Cygni A. The other star in the binary, smaller and cooler than the primary, is visible at right; a terrestrial planet in the system can be seen as a bright starlike point. At best, the large planet's existence is still only hypothetical, but perturbations in 61 Cygni's proper motion may be accounted for by a massive dark body such as this. Any small planets would not be massive enough to be detected at all from Earth. Artwork by Adolf Schaller.

Astrometry is the study of star positions in the sky. It's both an old and very conservative branch of astronomy, and might be compared to stellar bookkeeping — with its scientific practitioners (astrometrists) being the green-visored, bespectacled accountants of the smallest and largest positional figures in the universe.

Who would believe so stable a field could produce unconservative excitement? Yet that's what astrometry is doing to the world of astronomy today. To substantiate the possibility of life (intelligent or otherwise) in the universe requires the basic premise that other solid planetary bodies also exist somewhere besides our own solar system. A haphazard search for such planets, though, would be a waste of time and effort, simply because there's no way of telling from a star's physical characteristics alone whether or not it has planets.

This is where astrometry comes in. The patterns of motion that would reveal an unseen planetary system might be hidden somewhere in the stars' paths through the sky. The astrometrist's job is to measure tiny variations in a star's position, account for all the known sources of movement (such as parallax and proper motion), and examine the remaining data for this hidden pattern. If it's there, he can hypothesize the existence of large Jupiter or Saturn sized planets in orbit around the star. Although the detection of Earth sized planets is presently beyond our capability, the presence of the larger bodies can give us a clue to the kinds of stars around which planetary systems, and perhaps Earthlike planets, might form.

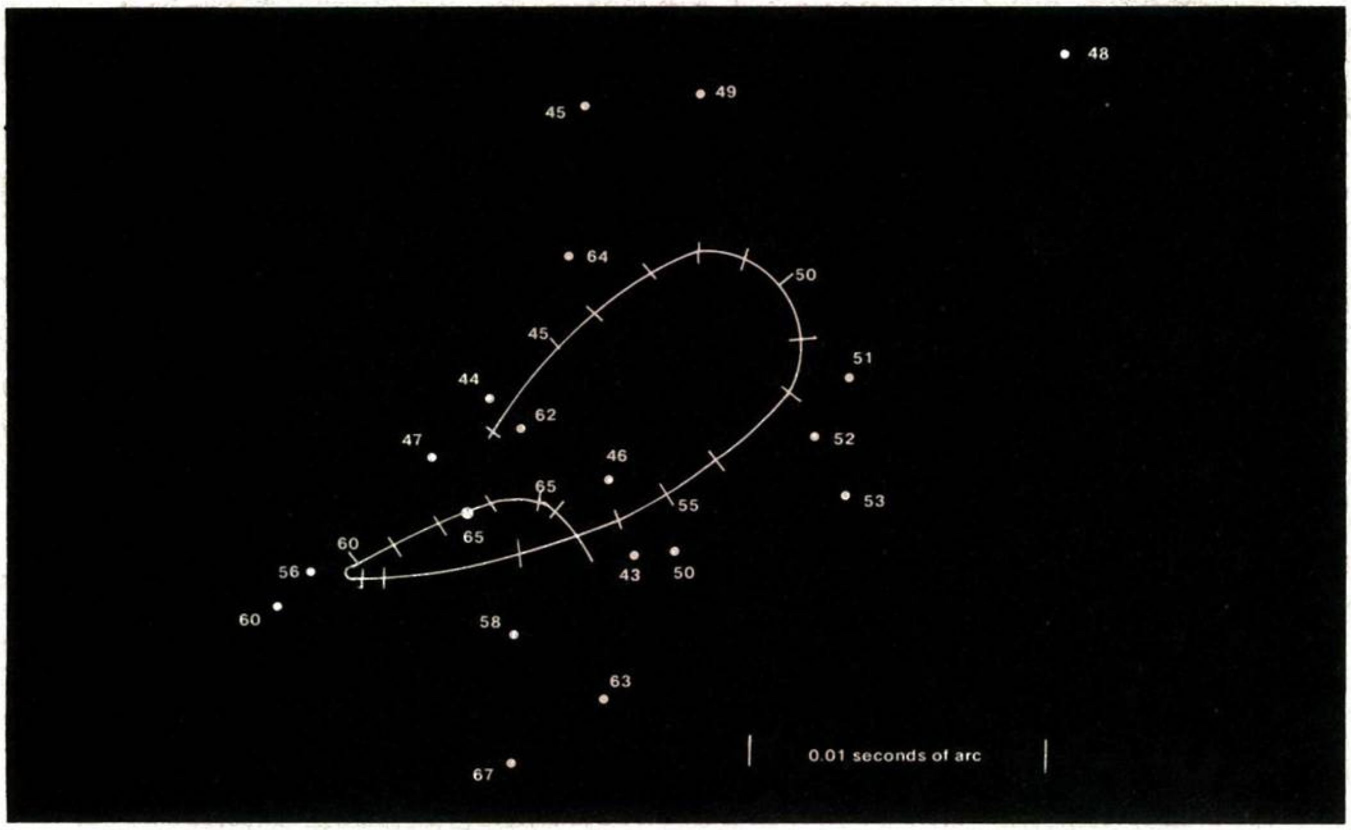
If we can positively identify stars that have families of planets, our search for life will be that much easier. The problem lies in determining which stars are likely to have them, so we can concentrate our efforts on those stars. How does the astrometrist carry out this identification process?

Imagine two people dancing a polka. As they whirl about to the music, each person — pulled by the other — moves in a series of circles across the floor. Now imagine that one of the dancers is invisible; we can still tell he is there by the motion of his partner.

Since we can see the star and not the planet, the star is the visible "dancer" in our analogy. The motion of the star reveals the presence of the planet (or planets). Since a star is much more massive than a planet, our invisible dancer must be very "fat" — that is, the size of Saturn or larger — to perturb the star enough for us to detect its existence. Similarly, the star has to be "thin" (low mass). And the nearer our dancers are to us, the easier it is to see the visible partner being thrown around.

The majority of stars about which planets may circle would not necessarily be similar to the sun. If we

Of all the stars in the photo at left, only 61 Cygni (circled) wobbles enough to indicate the possible existence of a planetary system. Such a wobble is depicted in the diagram below; the probable path of Barnard's star over a 26 year period is shown by the curved line. The observed positions (dots) were used to calculate a path best fitting the data. On this scale, the star image photographed by the telescope is more than eight feet in diameter — showing how tiny the perturbation is. Diagram by David A. Schwartz.



The sun is located in a relatively isolated neighborhood. If it were situated at the center of a globular cluster such as M-92 (above) or an open cluster like one of the members of the Perseus double cluster (opposite), the stars, being more densely concentrated, would lie nearer each other. The wobble produced by planetary systems might then be more easily detectable. But gravitational effects, caused by the stars' concentration, would produce additional perturbations in their proper motions — enough that extrasolar planetary systems would still be extremely difficult to find. Above: Yerkes Observatory photograph; Opposite: Artwork by Adolf Schaller.

look at all the single (nonbinary) stars that are located within 15 light-years of the sun, we find that the average mass of all these stars is only about ¼ that of our sun. In fact, of the 60 nearest known stars, only five are as massive (or more so) than our sun; the rest are all less massive. The actual fraction of these smaller stars may be even higher: Any nearby stars not yet discovered would probably have low mass and be too faint to have been previously found.

Smaller mass stars are usually red in color and belong to spectral class K or M. Their surface temperatures are thousands of degrees lower than the sun's. Over 2/3 of the stars in the solar neighborhood have surface temperatures 6,000 degrees Fahrenheit or cooler (about 4,000 degrees Fahrenheit less than that of the sun). Low mass stars also have longer lives, since they use up their fuel at a slower pace, and will continue their nuclear reactions 20 times longer than our sun will.

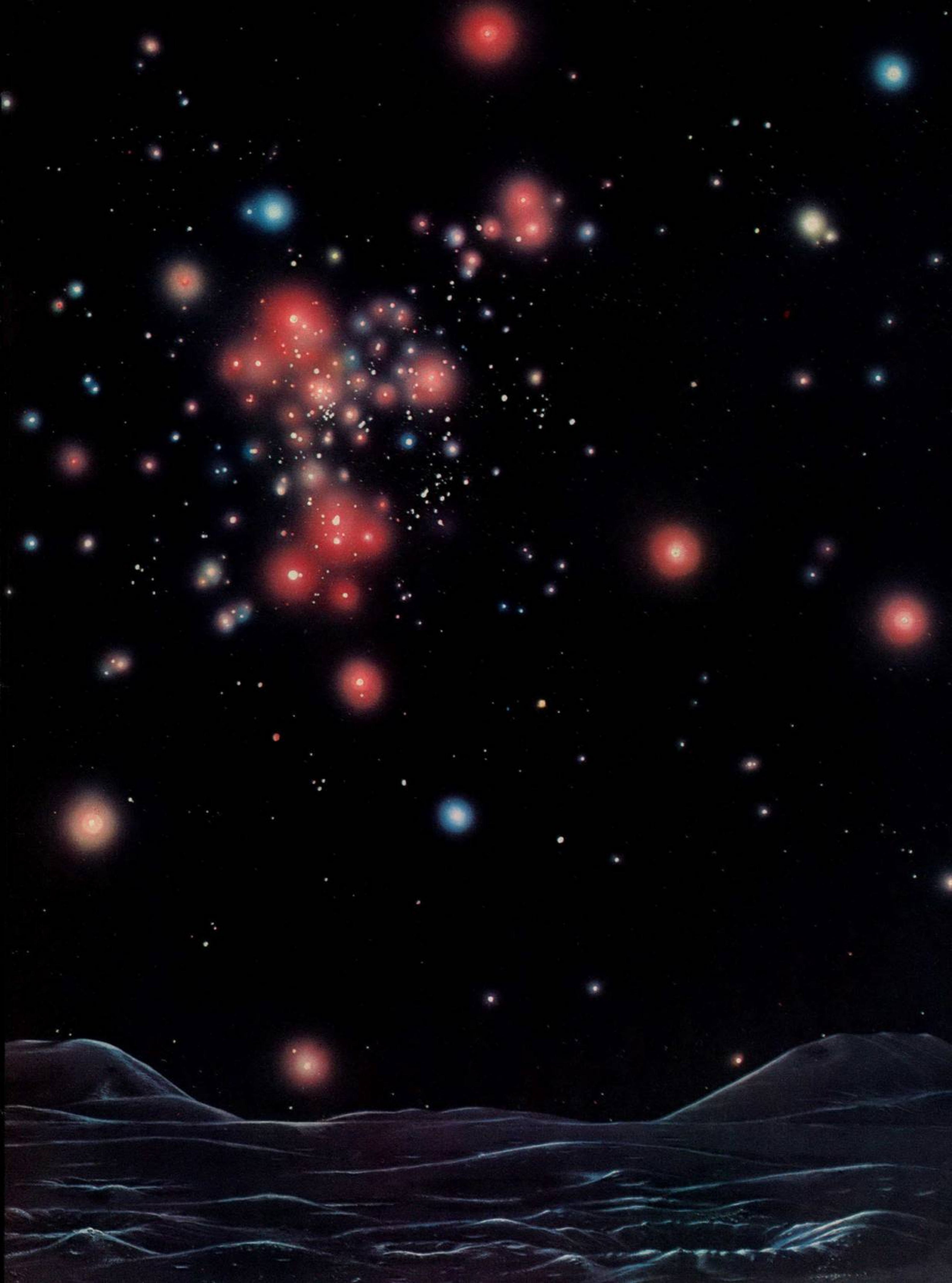
Therefore, we must look for planets in the vicinity of nearby low mass stars, if we want to obtain a true idea of planetary system frequency. The majority of planets will probably be found around smaller, cooler stars than the sun, because there are so many more of the former.

However, planets—no matter how massive they are — are literally lost in the glare of their parent stars. Direct observation is impossible because no existing telescopes have the necessary light grasp or resolving power. So even if we know *where* to look, the next step is to recognize *what* to look for.

The work of star measurement had been carried out visually for literally thousands of years, first with the naked eye and then the telescope. The invention of the latter allowed more accurate measurements to be made. But soon after photography was invented, astronomers recognized a new and far better method of finding star positions: Take a picture and measure the places of the stars from the picture! In order not to bend or distort the stars' positions, the photographic emulsion was coated on glass. In addition, the telescopes used to take the photographs were carefully kept unchanged over decades—an ongoing series of measurements would take that long to complete because of the extreme slowness with which stars' positions change. The telescope used in astrometric study must not be tampered with, for even such a simple operation as removing the lens to clean the glass can introduce errors if the lens is not replaced in exactly its former position.

Imagine a present day astrometrist in a long night's work. He may take 20 photographs on thick glass plates, using one of the carefully preserved refractors astrometrists have worked with for 80 years. Each plate must be carefully marked and

continued on page 14



$N = R_* f_p n_e f_l f_i f_c L$

by John W. Stein

Now that astrometrists have detected extrasolar planetary systems, the obvious next step is a search for intelligent life in the systems discovered. What are our chances of finding intelligence? The well-known equation formulated by Dr. Frank Drake, plus astrometric detection of planets, may help us make a reasonable guess of the number of civilizations waiting to be found.

Proposed in 1971, Drake's equation estimates the number of civilizations in our galaxy that can communicate with one another over interstellar distances. In the equation, shown here as our title, N represents the number of civilizations that have interstellar communication capability.

The equation might at first glance seem nearly unintelligible, but it can be deciphered by an example. Assume that an average of 10 new stars form each year in our galaxy (R_*), and that only 1 of the 10 will have a planetary system (f_p). If every new system has perhaps two planets upon which life *could* survive (n_e) — some systems will have more and some less, but the average is two — then each year two new habitable planets will be formed. Next, suppose that life actually *does* exist on one out of every four suitable planets (f_l). We arrive at an estimate of one life-bearing planet formed every two years.

What are the odds that intelligence will evolve on such a planet (f_i)? Let's assume that intelligence will appear on 1 life-bearing planet out of 100. If one such planet is formed every two years — or 100 every 200 years — then one intelligent species will evolve in our galaxy every 200 years. Suppose that half these civilizations learn to communicate over interstellar distances (f_c) — once every 400 years a civilization will learn to contact its neighbors. Finally,

if each of these civilizations lasts for about 1,200 years (L), and a new one arrives every 400 years at any given time there will be three intercommunicating civilizations in the galaxy.

The estimated value of N varies greatly from one study to another. In our example, we arrived at the figure three, but we can find estimates for N anywhere from one to one billion. The problem lies not with equation, but with our almost total ignorance of the proper values to assign its numbers and fraction on its right hand side. Since N is the product of *seven* uncertain quantities, we should not be surprised at the wide range of values derived for it.

We could conclude that any attempt to find a reasonable estimate for N is an exercise in futility. This is not the case, however; new astrometric techniques can greatly reduce the uncertainties in N. All our current estimates of f_p (the fraction of stars with planets) are based upon one known planetary system (our own), two or three possibles, and a body of theoretical work. We can get a much better idea of the proper value to assign f_p through a careful survey of the nearby stars for planetary systems, and thereby increase the accuracy of N. Long series of observations made on newly discovered systems may show that some of them contain more than one planet. Although present instruments enable only detection of Jupiter sized planets in a given system, theorists can test their calculations against actual planets and attempt to produce more realistic mathematical models. These then could be used to better predict the average number of habitable planets per system (n_e), increasing the certainty of the value we give to N.

Of course, the other variables in the equation will still be uncertain, but the range of values we give N will be narrower; we will be slightly closer to an answer to the question: Does intelligent life exist elsewhere in the universe?

John W. Stein received his degree in astrometry in 1973 from Case Western Reserve University in Cleveland, Ohio. He is presently doing graduate study at Allegheny Observatory in Pittsburgh, where he is employed as a senior observer.

continued from page 10

calibrated, and often more than one set of stars is recorded on it. The truly delicate work of the astrometrist begins after the plate is developed. The position of each tiny star image is measured on a huge, ultraprecise measuring machine, accurate to 1/100 the diameter of a hair. It is only by this tiny amount that star positions change, and precise measurements are vital.

From Earth, we can't detect the stars' wobble directly because Earth, Moving around the sun, makes the stars appear to shift back and forth. This motion is called *parallax*. But the astrometrist can calculate parallax out. Both the sun (carrying Earth with it) and the star, itself, are moving through space, producing an apparent shift in the star's position against the background stars. This apparent motion is known as *proper motion,* and it too can be accounted for with the aid of sophisticated calculations. Only a tiny residual wobble is left when the powerful computers have finished their work—a wobble so small that even the hairsplitting accuracy of the measuring machines can barely "see" it; a wobble all but lost in the grainy structure of the image on film.

To bring that wobble out, astrometry resorts to an old scientific trick: combining many measurements together and averaging them, again with computers programed to use every possible method of reducing observational error. The final numbers obtained, after decades of the most demanding mea-

Caption for pages 12 & 13

The perturbations in a star's proper motion that would indicate the presence of planets are extremely small — so small that, at present, no extrasolar planetary systems can be positively identified. A giant planet circling a low mass star, such as the red dwarf portrayed here, would probably be easiest to detect. The planet's large mass would have a greater amount of gravitational attraction, producing significant shifts in the star's motion — shifts that astrometrists on Earth can measure. Artwork by Rick Sternbach.

WHICH STARS HAVE PLANETS?

Star	R.A. (1950)	Dec.	Parallax (seconds of arc)	Spectral Class	Visual Magnitude	Mass (sun=1)	Detection Index
G 158-27	0^h04^m	-07°47'	0.224	—	13.8	0.1	1.0
Groombridge 34A	0^h15^m	+43°44'	0.282	M1V	8.1	0.29	0.6
Groombridge 34B	0^h15^m	+43°44'	0.282	M6Ve	11.0	0.15	1.0
Van Maanen's star	0^h46^m	+05°09'	0.239	DF3	12.4	0.7	0.3
L 725-32	1^h09^m	-07°16'	0.261	dMSe	11.6	0.15	0.9
τ Ceti	1^h41^m	-16°12'	0.277	G8V	3.5	0.81	0.3
L 1159-16	1^h57^m	+12°50'	0.213	dMSe	12.3	0.14	0.8
ϵ Eridani	3^h30^m	-09°37'	0.302	K2V	3.7	0.76	0.4
Stein 2051A	4^h26^m	+58°53'	0.2	M5	11.2	0.18	0.6
Stein 2051B	4^h26^m	+58°53'	0.2	Wd	12.4	0.5 (est)	0.3
Ross 47	5^h39^m	+12°29'	0.166	sdM4	11.6	0.18	0.5
BD +5°1668	7^h24^m	+05°22'	0.27	dM4	9.8	0.23	0.7
G 51-15	8^h26^m	+26°57'	0.272	—	14.8	0.09	1.3
Groombridge 1618	10^h08^m	+49°42'	0.222	K7V	6.6	0.51	0.4
Wolf 359	10^h54^m	+07°19'	0.429	dM8e	13.5	0.1	2.0
Lalande 21185	11^h00^m	+36°18'	0.396	M2V	7.5	0.29	0.9
Ross 128	11^h45^m	+01°06'	0.301	dM5	11.1	0.15	1.1
Lalande 25372	13^h43^m	+15°09'	0.205	M4V	8.5	0.33	0.4
LFT 1120	14^h31^m	-12°18'	0.16	M4	11.4	0.19	0.5
BD -12°4523	16^h27^m	-12°32'	0.249	dM4	10.1	0.22	0.7
AOe 173642	17^h36^m	+68°23'	0.214	M4V	9.2	0.28	0.5
Barnard's star	17^h55^m	+04°32'	0.549	sdM5V	9.5	0.15	1.9
Σ 2398A	18^h42^m	+59°33'	0.284	dM4	8.9	0.25	0.7
Σ 2398 B	18^h42^m	+59°33'	0.284	dM5	9.7	0.21	0.8
Ross 154	18^h46^m	-23°53'	0.345	M4.5e	10.6	0.15	1.2
G 208-44	19^h52^m	+44°17'	0.215	—	13.4	0.12	0.9
G 208-45	19^h52^m	+44°17'	0.215	—	14.0	0.11	0.9
61 Cygni A	21^h04^m	+38°30'	0.296	K5V	5.2	0.58	0.4
61 Cygni B	21^h04^m	+38°30'	0.296	K7V	6.0	0.46	0.5
Kruger 60A	22^h26^m	+57°26'	0.253	dM4	9.9	0.2	0.7
Kruger 60B	22^h26^m	+57°26'	0.253	dM4e	11.3	0.13	1.0
L 789-6	22^h35^m	-15°35'	0.305	M7e	12.2	0.15	1.1
Ross 248	23^h39^m	+43°55'	0.318	dM6e	12.3	0.13	1.2

The stars in this table are all those that lie within 15.5 light-years of the sun (with the exception of close binaries). The Allegheny Observatory in Pittsburgh is beginning an astrometric study of these stars in the hopes of detecting planets around them. The detection index indicates the relative sensitivity of the astrometric technique for each star — an index of 0.9 is sufficient to reveal planets the size of Jupiter.

surements, tell scientists how big that wobble is. Scientists can even learn the mass and period of the bodies that caused such motion.

Astrometrists have learned to be wary of errors that may crop up in their studies. But sometimes a mistake can slip by and the effects can be disastrous. One error can ruin a series of observations that took as long as 20 years to complete. Barnard's star is a case in point.

This star, located in the constellation Ophiuchus, is ideal for astrometric study because it is nearby and has a large proper motion. As a result, astrometrists have given it more attention than any other star. Three refracting telescopes — at the Allegheny Observatory in Pittsburgh, the Van Vleck Observatory in Connecticut, and the Sproul Observatory near Philadelphia — accumulated a large amount of data on Barnard's star over a period of years.

But a discontinuity appeared in 1949. In that year, the old retaining cell that held the objective lens in the 24 inch refractor at Sproul was replaced with a new one. Naturally, great care was taken to match the position of the new cell to the old one. But the match was not exact enough, and this tiny mismatch produced a slight change in the precise way the telescope lens formed a star's image on the glass photographic plates. The error was not immediately recognized, and as a result, the observed position of Barnard's star jumped — apparently showing a significant change in the star's proper motion. Astrometrists were tremendously excited, and advanced numerous theories — all suggesting planetary systems — to explain the jump. Years later, however, a thorough analysis of Sproul Observatory's data was made. When compared with information from Van Vleck and Allegheny, it showed that the jump never occurred but was caused by error introduced with the new lens cell — thereby invalidating all the planetary systems proposed by astronomers using that data.

The follow-up study didn't eliminate the possibility of planets around Barnard's star, though. Instead, revised data indicates that a system might exist, different from any of those spawned by the original data. If the new measurements are reliable, we can detect two major bodies in the system with orbital periods of 10 to 30 years and masses similar to those of Jupiter and Saturn.

Barnard's star is the only one around which astrometrists now seriously suspect that planets revolve. Epsilon Eridani, a star somewhat similar to our sun, was thought to have a planet about six times the mass of Jupiter, but new data has shown that may not be the case. New studies now underway, with the best modern techniques, may lay to rest — or revive — this ghost planet.

A seventh magnitude star known only as Lalande 21185 lies 8.1 light-years away in the constellation Ursa Major. Until a few years ago, this red dwarf was attributed with a companion that modern data has shown simply isn't there.

61 Cygni is a binary star — two orange stars (61 Cygni A is of spectral class K5, and B is K7) circling each other at more than the sun-Pluto distance, with a period of 720 years. This binary lies 11.2 light-years from Earth, and one of the components (61 Cygni A) was thought to have a massive planetary companion; new data from Sproul shows that this companion is unlikely to exist.

A massive planet orbiting the star BD +43° 4305 has been detected by one observatory. This data, however, will have to be confirmed by other observatories before it can appear in lists of extrasolar planets.

Of course, low mass planets may still orbit these stars, but they would produce wobbles far too small to observe and measure from Earth. Even the Jupiter-mass objects that may circle Barnard's star are not beyond question. The type of massive dark companion that would be easiest to find may turn out to be not a planet, but a very low mass dwarf star.

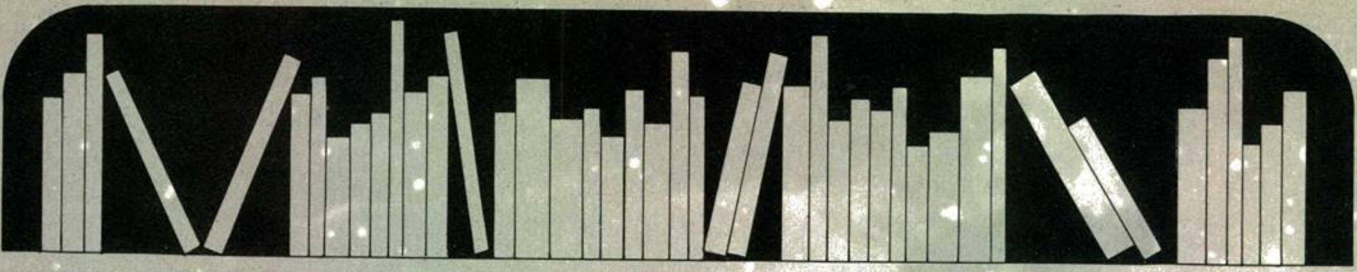
But even if our guess is right and these unseen bodies are actually planets, the two so far discovered are at least the size of Saturn. Intelligent life as we know it could not exist on such worlds, but only on smaller solid bodies, undetectable with present techniques and equipment. If we can't find Earthlike planets, is our search for life meaningless after all?

We must admit that any telescopes large enough to detect the wobbles caused by small planets could not be made until a date far into the future. And even if we discovered such planets, the time needed to send spacecraft or probes to them would be very great. But the detection of even gigantic planets, like those already found (or at least suspected), indicates the *type* of star around which planets form. We can thus direct our planetary search more carefully.

Allegheny Observatory is now actively searching for more stars with unseen companions. Its careful study of 33 nearby stars — those most likely to have planetary systems — could enable scientists to detect Jupiter sized planets near 15 of these select stars. Astrometrists are enthusiastic, even though they may not get answers for 30 or more years; the extreme precision needed in their work has taught astrometrists patience.

The excitement generated by any science is achieved only after years of careful and precise study. Once this is done, however, man can begin to obtain the benefits of scientists' rigorous work. Astrometrists, the bookkeepers of the sky, may soon be able to provide the basic figures necessary for man's first tentative steps toward discovery of life beyond our solar system.

The ideas in this article are developed in more detail in "On the Astrometric Detection of Neighboring Planetary Systems" by George Gatewood, published in the January 1976 issue of **ICARUS**.



ASTRONOMY REVIEWS

Aeronautics and Space Report of the President, 1974

NASA, transmitted by GERALD R. FORD

141 pages, $2.10*

What is the United States government doing in space? Most of us can name the major projects of NASA, and a few of us have heard of what the Defense Department is also working on. But how about the Department of Commerce, the National Science Foundation, the Federal Communications Commission, or the Department of Agriculture? It may come as a surprise to learn that these and other agencies have their own space programs. It will be an even greater surprise that many of these efforts are of great interest to astronomers.

In accordance with the law establishing the National Aeronautics and Space Administration in 1958, the president of the U.S. is required every year to submit a report to Congress on the preceding year's efforts in space and aeronautics. This report was put together by NASA for that purpose.

As could be expected, half of the book does deal with NASA and the Department of Defense. This is an excellent summary of their space programs in progress and planned, as well as interesting and rarely seen details on operational aspects of space exploration such as tracking sites and dissemination of data once it is received from outer space. NASA summarizes its Earth application programs and its scientific programs with special sections on the Orbiting Solar Observatories, the International Sun-Earth Explorer, Helios, the Orbiting Astronomical Observatory, and plans for the High Energy Astronomy Observatory, the Large Space Telescope, and the International Ultraviolet Explorer. Sounding rocket experiments are also detailed, along with planetary probes in the Mariner and Pioneer program.

Meanwhile, the Department of Commerce is studying the sun in order to measure its effects on Earth's atmosphere and weather; this involves such disciplines as astrophysics, interplanetary physics, magnetospheric physics and ionospheric physics. The National Science Foundation is doing its part through its role in sponsoring Kitt Peak National Observatory, the National Radio Astronomy Observatory, and the National Astronomy and Ionosphere Center. Descriptions of these sites, along with the Cerro Tololo Inter-American Observatory in Chile, are important to all astronomy students.

The list would not be complete without mention of the Smithsonian Astrophysical Observatory and its work on extraterrestrial materials and in high energy astrophysics. This leads to the role of the Atomic Energy Commission and its special radiation monitoring satellites. The AEC (now ERDA — the Energy Research and Development Administration) also built the power units for Pioneer-Jupiter, the Viking landers, and the Mariner-Jupiter-Saturn probes to be launched in 1977.

Closing its well-done role as a survey of space, the book has several excellent appendixes dealing with world satellite launch activity, a complete list and description of all U.S. 1974 space probes, and brief histories of all U.S. applications and scientific satellites since 1970. Manned space flight tables, descriptions of space launch vehicles, and a number of budget charts are also included — making this report a useful reference book for any large library on space and astronomy in the 1970s. *James E. Oberg.*

**Stock number 041-003-00005-7, for sale by Superintendent of Documents, Washington, D.C. 20402.*

Astronomy and Cosmology: A Modern Course

by FRED HOYLE

712 pages, hardcover, $15.95
W.H. Freeman (1975)

A science historian once lamented that the 18th century was about the last era in which a learned man could know all human knowledge. Since then, knowledge (or at least data and information) has mushroomed, and people become specialists who know more and more about less and less. On some frontiers of knowledge such as astronomy and nuclear physics, scientists must be continually "unlearning" old theories and learning new ideas.

Hence, when a book comes out promising to cover all of what is known about the universe, a reviewer approaches it with caution. When the author is a brilliant but erratic astronomer (creator of some of the best and worst science fiction of the last 20 years) known for his detours as well as his insights, additional wariness is called for.

This book is a grandiose attempt at a vision of "the big picture" of the universe. Chapter by chapter, a revelation becomes clear to the reader: The attempt is a success! Hoyle has really "gotten it all together" in this ambitious and far-reaching project; the book is excellent.

But, one must ask, excellent for whom? It is designed as a textbook for a college course (and not an introductory one, either, unless it lasts a full year or more). It can serve as an update or a review for a practicing astronomer or for a very well-informed amateur. It can serve as a capstone to the self-education of other amateurs, or as a readable reference book for anyone who is not yet ready to tackle the big picture. Lastly, its sweep and scope can serve as a humbling experience for anyone who wants to contemplate the cosmos, and as a model for what a really readable college textbook should be like.

Perhaps it would be easier to catalog what is not covered here than what is. After a first look at the universe from Earth's point of view, Hoyle reviews the principles of particle and radiation physics which allow us to observe distant objects at all. Nine special appendixes examine detailed technical questions which can be skipped by the casual reader (dozens of similar sections are included later throughout the book).

Next, questions on the formation of stars and the origin of the galaxy are raised. Fifty pages are devoted to atomic structure, nuclear energy, and the history of matter. The "cooking" of heavy elements is described in a precise but straightforward special section.

The big picture is then approached from a new direction: the history of astronomy and the unraveling of mysteries of the solar system. The planets and theories of their origin are described, and a chapter on life in the universe comes next. Crucial sections on radio astronomy and cosmology close the book.

Having experienced great pleasure with this textbook — its illustrations, general structure and narrative style — a critical reader can then in all fairness take the author to task for some minor but glaring errors. Several of the illustrations (selected with great care from earlier books) are reproduced with their original misspellings intact. Hoyle should someday finally decide to switch completely to the metric system instead of mixing tons, square centimeters, angstroms, pounds, and other units (and the basic metric unit of length is the meter, not the centimeter!).

Perhaps the weakest part of the book is the exobiology section; the biochemistry introduction is excellent, but information on life's initial steps from chemicals to amino acids to proteins to cells is scanty. Further, Hoyle's explanation for where Earth got all its volatile elements (a chance collision with a snowball from the region of Neptune) is not the only, nor even the most popular, theory. His description of the formation of the moon's Mare Orientale feature is based on a widespread but incorrect assumption. Sunlight pressure is not the only cause of comet tails (there is also the solar wind, which may create a second tail). The role of the redshift in determining galactic distances is ignored. And, the Crab nebula supernova did not occur 1,000 years ago (the light had been traveling for 8,000 years before it arrived at Earth 1,000 years ago).

Lastly, Hoyle is simply wrong when he asserts (three times) that the heliocentric and geocentric solar system models are physically equivalent and depend only on the observer's point of view. The difference "has no physical significance" according to Hoyle, and he is incorrect: Inertial frames of reference are not arbitrary. It would be equally absurd to claim that the whole planet Earth revolves around a small Apollo spaceship instead of vice versa.

These criticisms would be characteristic of a picky perfectionist and not worthy of much attention, but for one other weakness of the book: Hoyle knows a tremendous amount about astronomy and cosmology, but he gives few hints about other theories or areas of controversy and debate. His metaphors, study questions of social significance, and listings of areas of current uncertainty and mystery all comes across very well. The flavor of his famous lecture techniques comes across successfully, offering new rewards on every page. But a reader should be aware that everything presented here is just "the universe according to Hoyle." It is an exciting universe, nevertheless. *James E. Oberg.*

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FUTURE SPACE PROGRAMS 1975

Hearings
356 pages, $3.20*

Volume I
70 pages, $.95**

Volume II
986 pages, $7.60***

This is the raw material of a dozen future books on space exploration. The three volumes are a mine of advice from dozens of scientists, economists and philosophers on what course the United States should follow for the next quarter century in space.

While Apollo and Soyuz space capsules were linking up in space last July, a Congressional subcommittee was convening another meeting on Capitol Hill. The lawmakers wanted to find out what choices were available for space exploration in the future.

The formal hearings consisted of live testimony and questioning of a number of specialists. Space prophets such as Gerard O'Neill (describing plans for space colonies), Arthur C. Clarke (reporting on his latest novel), Donald Hearth (NASA chairman of the "Outlook for Space" study) and Carl Sagan (astronomer and comparative planetologist) presented their views and discussed them with the perceptive, interested and enthusiastic Congressmen. Space may be boring to most people these days, and the only quotations from Washington seem to be from antispace politicians. But this important group is a vital exception. Following the hearings, the subcommittee recommended a 25 percent *increase* in the NASA budget.

More than technological predictions came out of these sessions, although there were plenty of those. Economics and management were important issues. Philosophy also appeared, such as in the comments of **Saturday Review** editor Norman Cousins: "What was most significant about the lunar voyage was not that men set foot on the moon but that they set eye on Earth.... We went to the moon not because of our technology but because of our imagination."

The three books consist of an unnumbered "proceedings" volume plus two numbered books — one a summary and the other a massive compendium of submitted papers. Volume I includes most of the "quotable quotes" and major conclusions, and is the minimum which an interested reader should obtain.

Volume II is the real meat of the study: papers submitted to the committee by invitation from specialists who could not personally attend. The prominent opinion leaders are there — Isaac Asimov, Krafft Ehricke, Bruce Murray, Neil Ruzic, Edward Teller, Wernher von Braun and others. Topics of space engineering, space applications and space science are covered in detail.

There are 100 pages on interstellar exploration, along with a half dozen separate articles on space astronomy. Even the distant study of other planets is eloquently defended by geologist Murray, quoting from his new book: "I emphasize the significance of the studies of our companion planets to an Earth undergoing global modifications as a result of current human activity. I suggest we should inquire not why are they uninhabited, but rather why is Earth habitable?"

This government anthology can provide months of fascinating study. Buy it and read it now, or wait two years and read parts of it here and there in other writer's books. *James E. Oberg.*

By U.S. House of Representatives Committee on Science and Technology, Subcommittee on Space and Science and Applications. Written at adult level.

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DUST CLOUDS AND ICE AGES

By

Gerrit L. Verschuur

We might consider all Earth life, including ourselves, the result of a chain of accidents. At any point along the evolutionary line, events could have taken an alternate path and brought about an entirely different world than that in which we live. It was only by sheer chance that the "proper" events occurred to ensure humanity's existence.

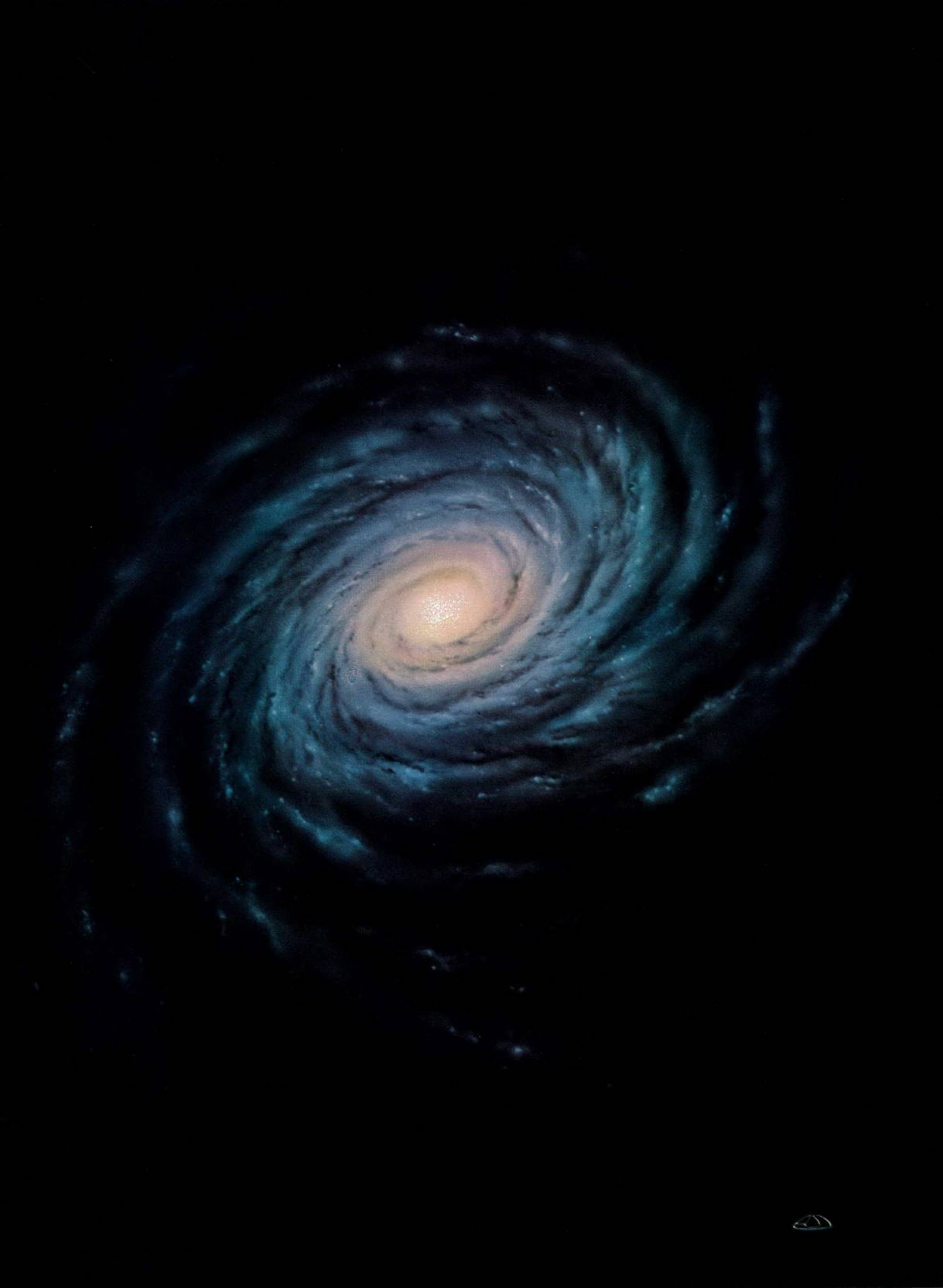
Despite this, however, we usually think of life on Earth as being somehow safe from extraterrestrial influences, and only the events that take place on the planet have any bearing on the future of Earth species. We know, for example, that ice ages have had a vast influence on the evolution of Earth life, but it is only now becoming clear how integrally they are related to galactic events.

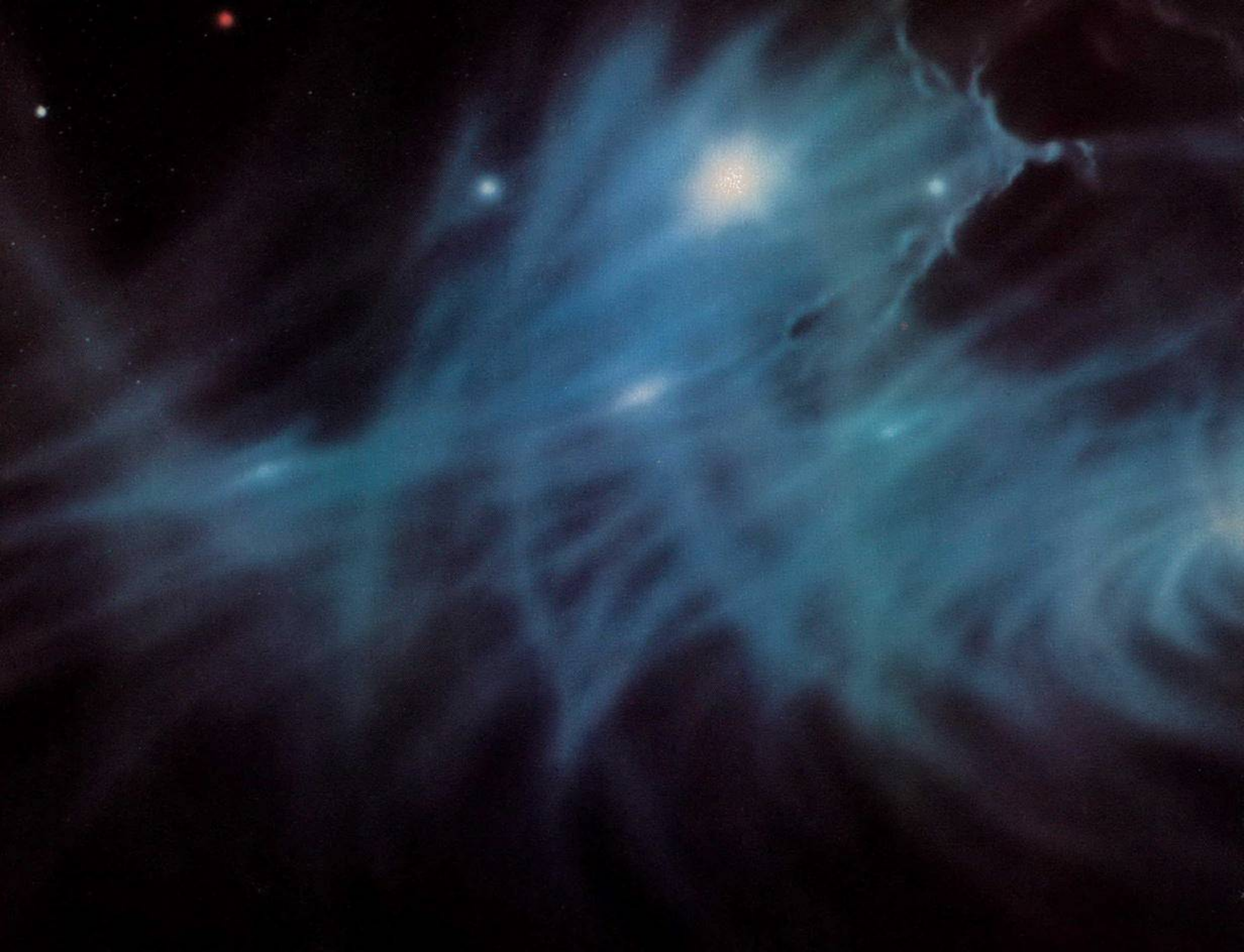
During the ice ages, various species were forced to move about the planet's surface in search of the warmer climates to which they were accustomed. Some forms of life suffered if they could not suitably adapt; others became extinct. In addition, glaciers rolled down over Earth's surface, molding it and leaving behind new terrain when they retreated. In fact, the ice ages may actually have helped create the conditions whereby life was able to originate. The complex molecules necessary for life to begin could only emerge if very cold temperatures prevailed sometime in the early history of the planet.

If another ice age were to occur, the disruption to civilized, industrial life would be staggering. We need only imagine the devastation that would befall Europe if ice sheets covered most of the continent, as has happened in the past.

Still, we think of the ice ages as a purely terrestrial phenomenon, unrelated to larger chains of events. But now scientists have proposed a theory relating Earth's ice ages to certain effects that take place on a galactic scale. According to this theory, ice ages occur only when the sun is located within a spiral arm of our galaxy—particularly when the sun moves into a dust cloud inside such a spiral arm. The concentration of dust can bring another chain

The spiral pattern in a galaxy like the Milky Way is produced by a wave of density variation. After its creation, the wave rotates around the nucleus, separating the material in the galaxy's outer sections into spiral arms. Vast accumulations of interstellar gas and dust pile up before the wave on the inner edges of the arms. As the sun travels through the galaxy, its passage through such a massive dust cloud can theoretically begin a series of events — *which could result in an ice age on Earth.* Estimated time scales for Earth's ice ages and for the sun's passage through spiral arms correlate closely, indicating the possible validity of the theory. Artwork by Adolf Schaller.





Stars form within huge clouds of interstellar gas and dust. This material coalesces in a manner similar to that shown in the above painting, in which a condensation of matter is reaching the point where nuclear ignition begins and a star bursts into life. The densest dust clouds, where star birth is most likely to occur, are found along the inside edges of a galaxy's spiral arms where the material is compressed most tightly. The density wave that rotates around the galactic nucleus — and forms the spiral pattern — piles up gas and dust before it and leaves a trail of newly formed stars in its wake. This is why the youngest, brightest stars in a spiral galaxy are located in the spiral arms. If the sun were to move into a dense dust cloud, the material in the cloud would still be very tenuous. But infalling material could sufficiently brighten the sun to bring about climatic changes on Earth. Artwork by Adolf Schaller.

of events into being, causing great modifications in Earth's patterns of life and evolution.

To understand the theory, some background information is necessary; we need a quick overview of galactic structure. Galaxies are, as we know, huge conglomerations of stars; many of them have flat disk shapes. The youngest, brightest stars in these galaxies are arrayed in spiral patterns around a nucleus that contains older stars. Large accumulations of gas (mostly hydrogen) and dust are also found in the spiral arms. A galaxy with these characteristics is called a *spiral galaxy*.

There are many galaxies that show no spiral pattern at all, such as *elliptical galaxies*. These, as the name suggests, have round or elliptical shapes and contain no interstellar dust and little gas. *Irregular galaxies* also are without the spiral pattern; in fact, they show no ordered pattern at all, but contain the same proportions of stars, gas and dust as spiral galaxies.

The term "spiral arms" may create a mental picture of two armlike appendages issuing neatly from the galactic center. While this is true of a few spiral galaxies, the majority contain more than a mere two spiral arms. In addition, the arms usually don't simply reach straight out from the nucleus. In some tightly wound spirals, the arms make several turns about the nucleus before joining it. Other spirals have a much more open pattern; the arms reach far from the nucleus without making even one complete turn around it.

Our sun exists within a spiral galaxy — a conclusion that scientists have reached only after careful study of the distribution of stars, gas and dust in the solar neighborhood, as well as through study of radio signals emitted by distant hydrogen clouds. Our location inside the galaxy makes it difficult to determine the entire galaxy's appearance; we can

never get outside it for a clear perspective. We can see other galaxies, though, and many of them show clear spiral structure , enabling us to get an idea of how the Milky Way must look from "outside".

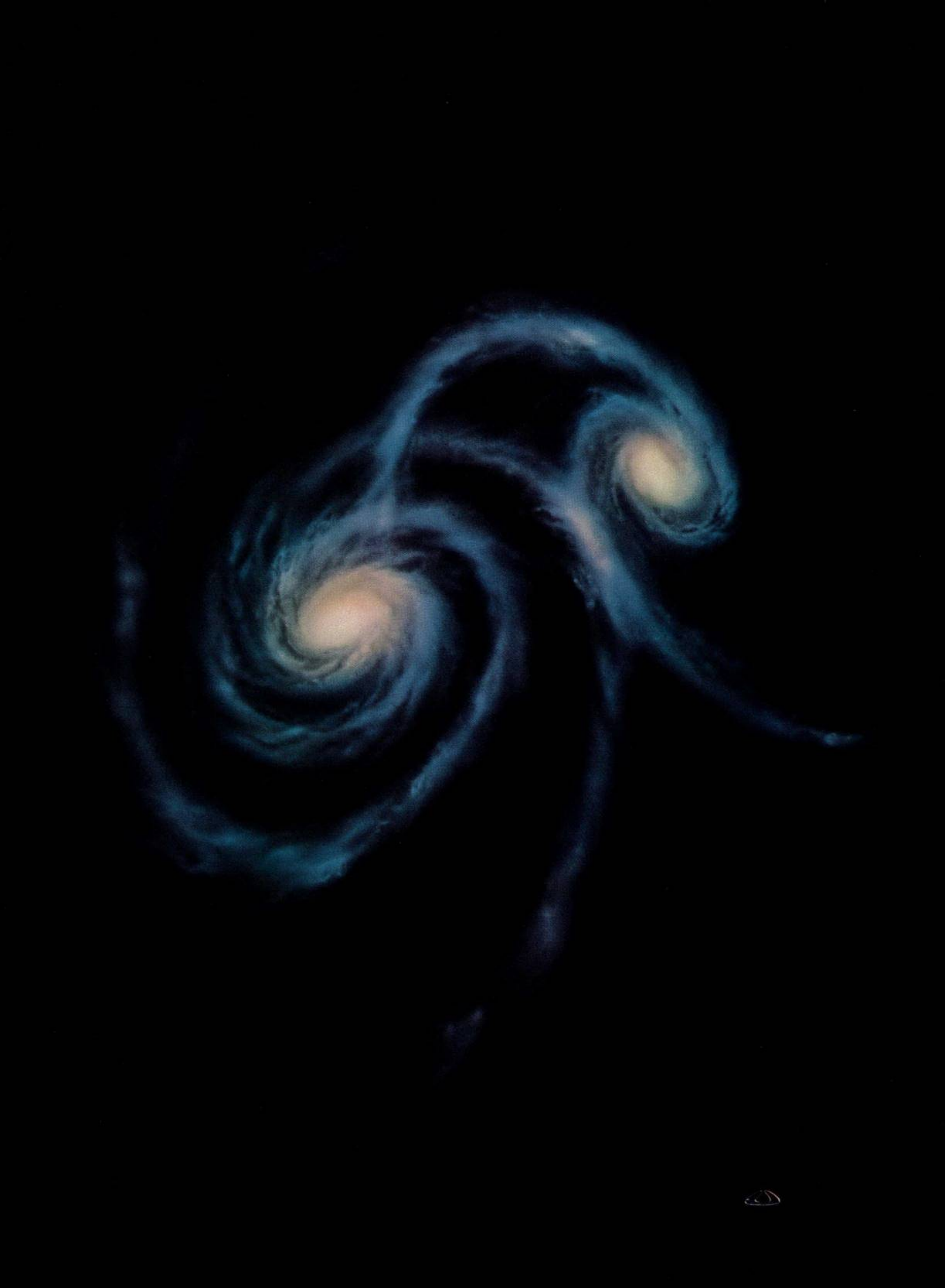
We know that all the galaxies, including our own, are rotating. The sun and its planets are moving around the center of the Milky Way at about 150 miles per second, taking 200 million years for one complete orbit. The period of time it takes for the galaxy to rotate once is called a *galactic year.* In a rotating spiral galaxy, we might expect the arms to wind up tightly, much as a watch spring does. After a few galactic years, the spiral arms should become so tightly wound that they blend into the nucleus and into each other, and disappear. But the spiral structure still exists, even in galaxies that we know are billions of years old (based on studies of the ages of stars within them)—despite the many rotations and windings made during their lifetimes. What keeps the spiral arms separate and distinguishable?

Until about 15 years ago, scientists thought the spiral arms might be kept apart by magnetic fields acting against the galaxy's rotation. But recent measurements of the field strength proved it far too weak to control spiral structure (at least on a galactic scale), and this theory is no longer subscribed to.

A more recent and more credible theory suggests that spiral arms are the result of a galactic wave structure manifesting itself as variations in density—that is, making some parts of the galaxy denser than their immediate neighborhoods. Such a wave rotates around the nucleus, moving with respect to the galaxy's stars and generating a spiral pattern. Thus the pattern we see today in a galaxy like M-51 (the well-known Whirlpool galaxy) is actually a wave of density variation. M-51 is so distant that the wave seems frozen into a single pattern. But millions of years from now, M-51's spiral pattern will be different than it is today. Density waves sweep by a given point in the galaxy at a measurable rate; those in our galaxy move past the sun at a fairly slow pace of about six miles per second.

Theories suggest that after a density wave is created, it will persist indefinitely, and a spiral galaxy will remain spiral for a very long time. But what generated the wave in the first place?

We might find the answer to this question by investigating interactions between galaxies. Experiments have been conducted with computers in which "galaxies"—hypothetical uniform disks of matter—



pass close by one another. These experiments show that mutual gravitational attraction causes the material in these disks (particularly in their outer sections) to be pulled into spiral-like streamers. Even after the two galaxies move apart and no longer interact, the density pattern generated would continue to move about the galaxy in the form of a wave.

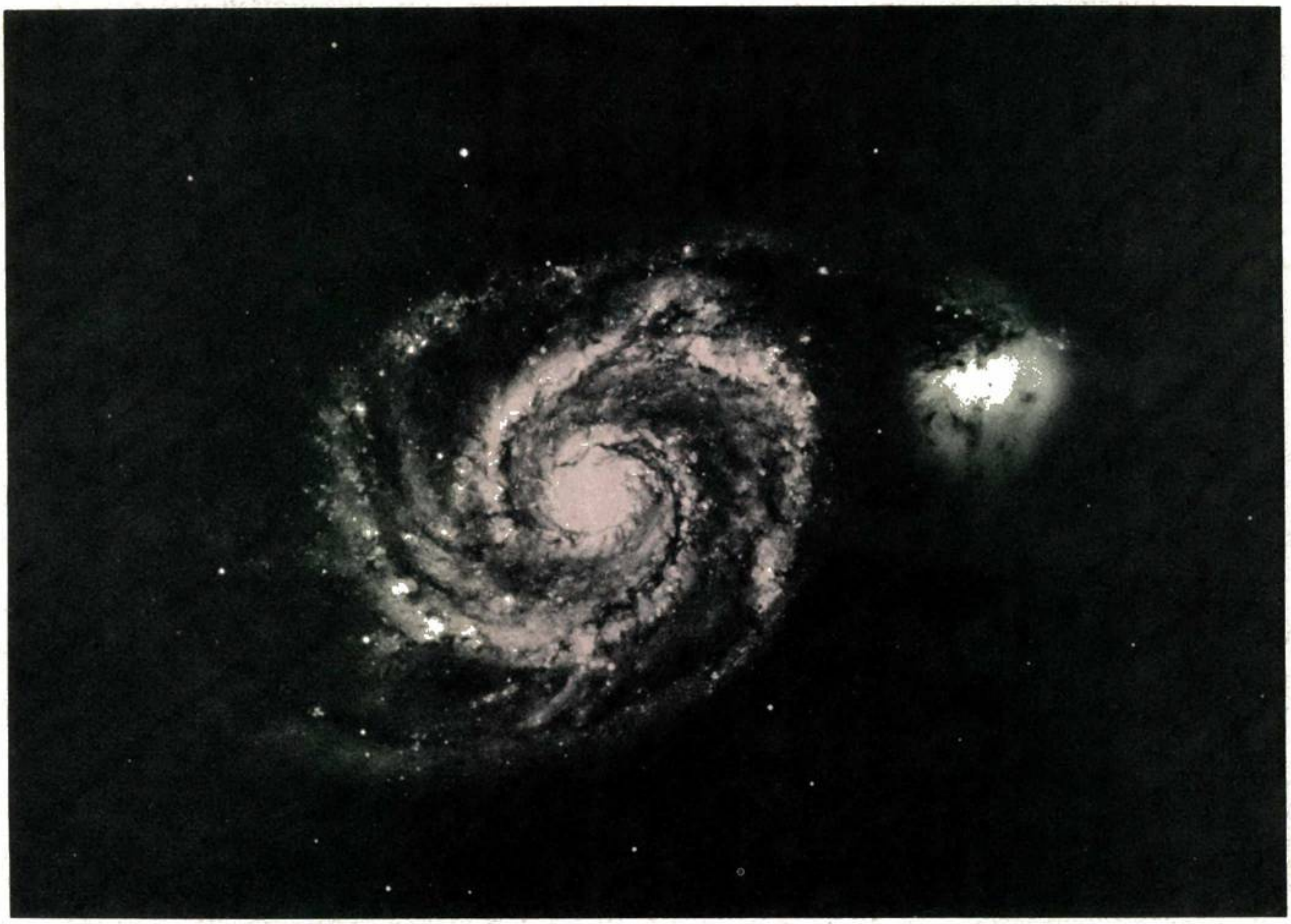
Our own galaxy has two nearby companions known as the Magellanic Clouds. These are irregular galaxies visible from Earth's southern hemisphere, about 160,000 light-years away. The clouds have apparently passed nearby the Milky Way in the past –possibly several times–and this close passage may well have triggered the density wave that makes our galaxy spiral. The theory has not yet been firmly established, but it's interesting to note that a large number of spiral galaxies have small companions. An obvious example is, again, M-51–one of the most perfect spirals in the sky. The Andromeda galaxy (M-31) also has several of these satellite galaxies.

Regardless of how it is generated, the density wave plays an important part in star formation. As the wave moves through the galaxy, the interstellar gas and dust accumulates before it; since stars are born in great clouds of this interstellar material, star formation is more likely to take place in this piled-up gas. We can therefore see the density wave in other galaxies as a spiral shaped region of star birth. The stars most recently formed are the brightest, which is why spiral arms are bright even though they are far less concentrated than the nucleus. The unformed gas and dust remaining after star formation is "pushed" by the density wave, and we often find the most dust in a galaxy on the inside edges of the spiral arms, where the wave has compressed the material tightly.

As the wave rotates around the Milky Way's nucleus, our sun during its lifetime drifts slowly in and out of spiral arms. Since the dust clouds are piled up on the arms' inside edges, the sun will sometimes find itself in regions where dust is relatively thick. At other times, it will lie in the dust-free areas between the spiral arms.

When the sun moves into a dense dust cloud, it will necessarily sweep up more material than it otherwise does–simply because there are more particles in the space through which it is moving at the time. The resultant accretion and infall of material could increase the sun's luminosity by as much as one percent–enough to cause climatic changes. De-

What makes a spiral galaxy spiral? One theory suggests that if two galaxies pass close by one another, gravitational attraction between the two may pull much of their material into spiral arms – as depicted in the painting at left. M-51, the Whirlpool galaxy (below), is apparently in the throes of just such a process; note the stream of gas and dust connecting the galaxy with its small companion. Opposite: Artwork by Adolf Schaller; Below: Hale Observatories photograph.



pending on the nature of the particles, brightness in some parts of the nonvisible spectrum may increase in greater percentages.

This brightening could easily occur in suitable dust clouds. But when the theory was first proposed, there was no evidence that our galaxy contained dust clouds dense enough to begin the process. We have gained much more information about interstellar dust clouds since then, including their sizes, densities, locations and, most importantly, their apparent preference to lie along spiral arms. Our present knowledge of the sun's motion through dust clouds could sufficiently account for the lengths and recurrence rates of Earth's ice ages.

Ice ages seem to occur every 250 million years, each lasting a few million years. The latter period of time is called an *ice epoch.* During an ice epoch, there are several distinct glaciations—what we normally think of as an ice age. Glaciations are separated by about 250,000 years. Earth's most recent glaciation ended only 11,000 years ago, about the time rudimentary civilizations began to arise.

All experts do not agree with these figures, but their rough equivalents are generally accepted: a few hundred million years between ice epochs, a few million years for each ice epoch, and several glaciations lasting less than 100,000 years each.

How well do these numbers correlate with the time scale estimated for the sun's passage through successive spiral arms? We know approximately how fast the density waves pass the sun, and also the width of a typical spiral arm. Therefore, the time elapsed between the sun's spiral arm passages can be calculated at a few hundred million years. If it's true that the dust in the Milky Way is mainly confined to a relatively thin lane on the inner edges of the spiral arms, the time needed for the sun to traverse that lane is a few million years. Finally, we know the typical size of an individual dust cloud in this lane, and we also know roughly the number of clouds in a given volume of space. We can calculate that the sun would spend about 50,000 years inside a typical dust cloud, moving in and out of these dust clouds every few hundred thousand years.

The striking similarity between both these sets of numbers is a good indication that solar brightening within a dust cloud is a major factor in causing Earth's ice ages.

Following an ice epoch, a few hundred million years would pass during which no ice ages would occur. The sun would again be roaming between the spiral arms, or at least in their outer sections where there is much less dust.

Studies made of lunar soil samples obtained by the Apollo missions lend support to the dust cloud theory. The samples were taken from various depths of the surface in order to investigate conditions that prevailed on the moon at different times in the past. Careful analysis of the samples reveals periodic increases in the amount of micrometeoroids falling onto the moon in the past—increases separated by a few hundred million years, thus hinting at a confirmation of our ice age/dust cloud model.

Until recently, scientists thought that micrometeoroids originated in the asteroid belt. We now know this is not the case, and the lunar samples indicate that the solar system must sometimes pass through regions of space containing denser concentrations of micrometeoroids—that is, dust clouds. The dust, of course, falls not only into the sun, but onto the planets. In fact, if comets (which are composed mainly of "dusty" material) are gathered up by the sun as it moves about in space, their number may increase when the sun moves through dense dust clouds.

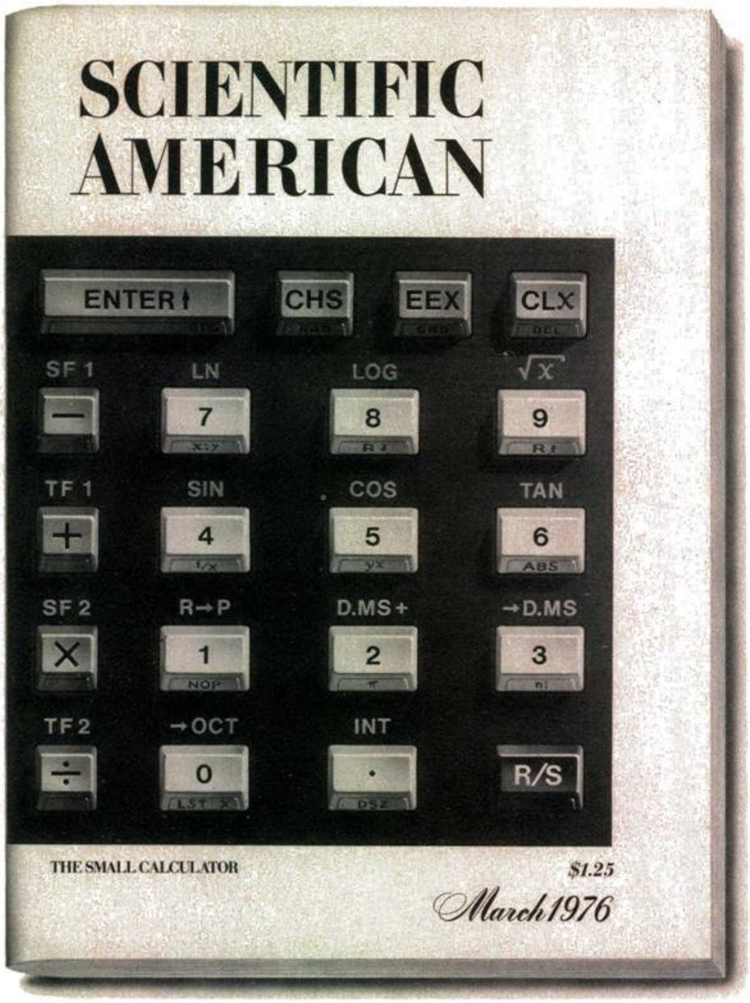
We must note that a dense dust cloud is not something obviously visible from Earth. To our eyes, it would make no difference whether we were inside or outside a dense cloud—our skies would look the same either way. The actual amount of material involved is extremely small no matter how we look at it. A dense dust cloud probably contains about 10 million particles per cubic centimeter, as opposed to approximately 100 in a "normal" cloud. But even 10 million particles is much less concentrated than the best vacuum we can manufacture on Earth.

It's much easier to examine distant dust clouds than to study those nearby. Dust clouds are harder to see when they are close to Earth because the little matter they contain is so diffuse. A dust cloud must be seen in contrast to its surroundings to be visible. If we were—or are—within a dust cloud that covered the entire sky, it would be unrecognizable because there would be nothing with which to contrast it.

There is thus no way of telling the extent of the dust clouds that lie just ahead of the sun's path, and it's impossible to predict when the next ice age is due to arrive.

Recent attempts to find the shape of the galaxy's spiral pattern should theoretically allow us to discover whether the sun is inside or outside a spiral arm at present. But the studies don't give a clear enough picture for us to predict the location of the nearest dust cloud. However, in view of our recent emergence from the last ice age—or dust cloud—it's unlikely that the sun has completely left the dust lane. What is far more probable is that we will enter another cloud before long.

Discoveries such as these bring home with repeated emphasis the interdependence between life on Earth and seemingly unrelated cosmic events. The ice ages have had more complex origins than was once suspected, and episodes in the life of a huge galaxy ultimately bear strongly on the course of Earth life. The series of accidents that has resulted in ourselves is very much larger than we normally imagine—so of all the wonders to be found in the universe, perhaps the greatest is our own existence.



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THE CONSTELLATIONS' CHANGING FACES

by

Henry J. Phillips

The discovery that stars move would have come as quite a shock to the ancients or the scientists of the Middle Ages. To these people, stars were fixed: Earth was the center of the universe, around which everything else revolved — sun, planets and stars. And while the sun and planets changed their positions in the sky, stars did not. Certainly the visible constellations changed from season to season, but they were in established and unalterable patterns. A popular notion of the time (one that was accepted by most of the learned) was that stars were encased in a crystalline sphere, all at one distance from Earth.

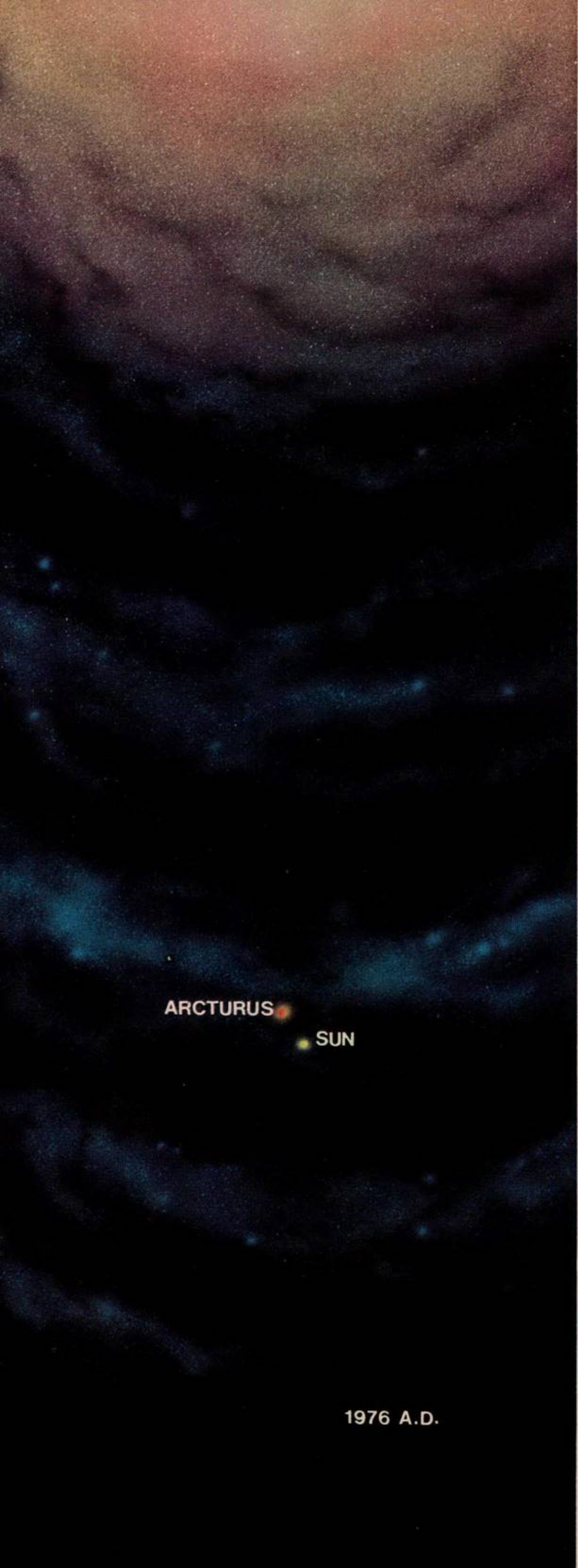
But discoveries made during the Renaissance forced a re-examination of this picture of the cosmos. The geocentric universe was stagnant and ready to collapse under its own weight. Fresh knowledge made it less and less credible, and the discovery of stars' proper motion drove the final nail into its coffin.

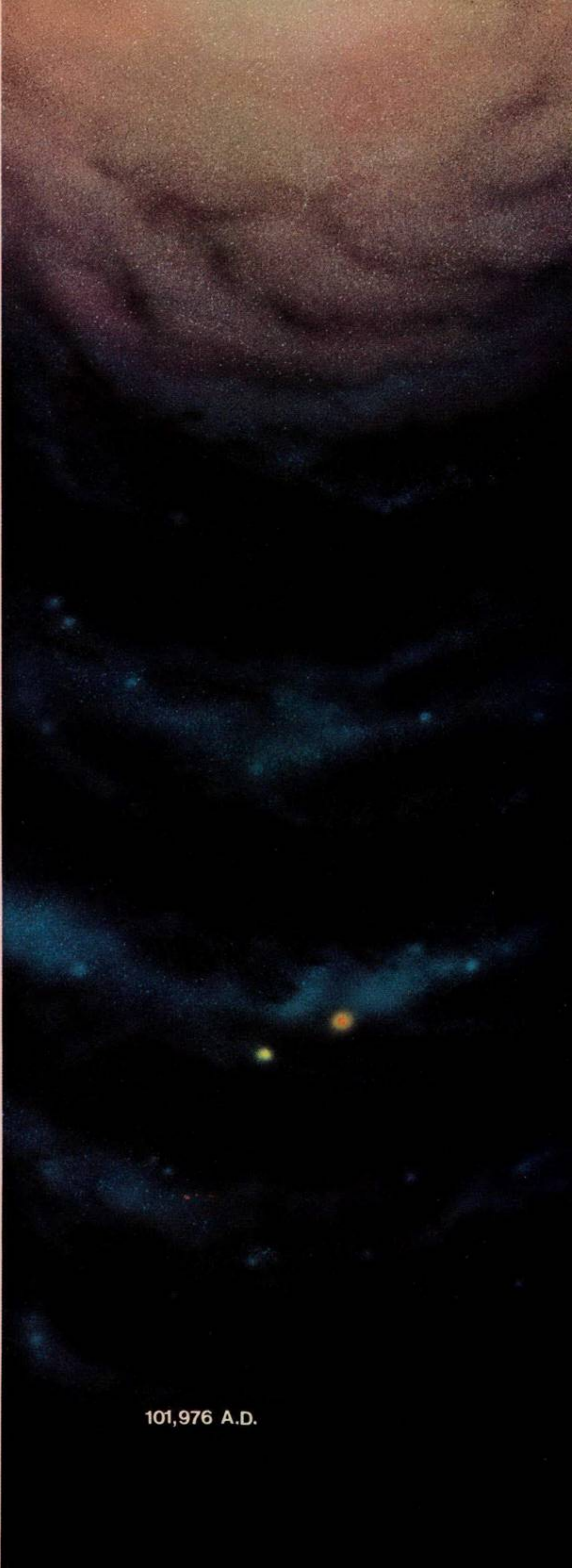
In 1718, British astronomer Edmund Halley was examining some of the ancient calendars and star charts that had existed for centuries. Among these was the famous **Almagest** of Ptolemy, written in the second century A.D. After puzzled calculations, Halley found that some of the brighter stars–including Sirius, Arcturus and Aldebaran — had different positions in the sky than those listed by Ptolemy. Earlier, anyone's normal reaction to this discovery would have been that Ptolemy had incorrectly recorded the stars' positions. But 18th century scientists — and Halley most of all — were no longer prepared to believe that such differences were due to earlier mistakes rather than actual changes. Halley noted that most of the other recorded stars were still in their recorded places, and he reasoned that a scientist as conscientious as Ptolemy would not have misplaced such important stars to so great an extent–a full degree of arc, in some cases. Halley reached the only possible conclusion: The stars had actually moved.

By 1718, many astronomers knew the stars' true nature. They were suns like our own, so far distant that they appeared only as points of light. Also, Halley was a student of Sir Isaac Newton and a firm exponent of Newton's gravitational laws. Halley found it simple to combine the two bodies of knowledge and hypothesize that all these suns were, in fact, moving through space and not fixed in their positions at all. When he published his discoveries, Halley's ideas were almost immediately accepted throughout the astronomical field. The "heaven of the fixed stars" was gone forever.

It's easy to understand why no one had noticed proper motion before, over periods of thousands of years. The stars are so far away that even the speediest present no change in position to the naked eye over a person's lifetime. For instance, Arcturus is

Unlike some stellar motions that are primarily visual illusions, proper motion is the result of a star's actual path through space. Different stars move at different velocities; our sun moves at 12 miles per second, while Arcturus has a speed seven times as great. Since the two stars move almost in opposite directions, their positions relative to each other will change drastically over the next 100,000 years. Arcturus will move more than 40 degrees southwest of its present location in our sky. Artwork by Victor Costanzo.


ARCTURUS
SUN
1976 A.D.


101,976 A.D.

considered quite a fast moving star—but in 1066, at the time of the Battle of Hastings, it was only the width of a full moon farther north-east than it is today.

It is important to distinguish between *proper motion* and the *actual motion* of stars. Although the stars are moving through space, proper motion refers only to an apparent movement— similar to the retrograde motions of the planets which sometimes appear to be traveling backward, but are not really doing so.

A star's proper motion is the rate at which its direction in the sky shifts from one year to the next. The actual amount of change depends on several factors:

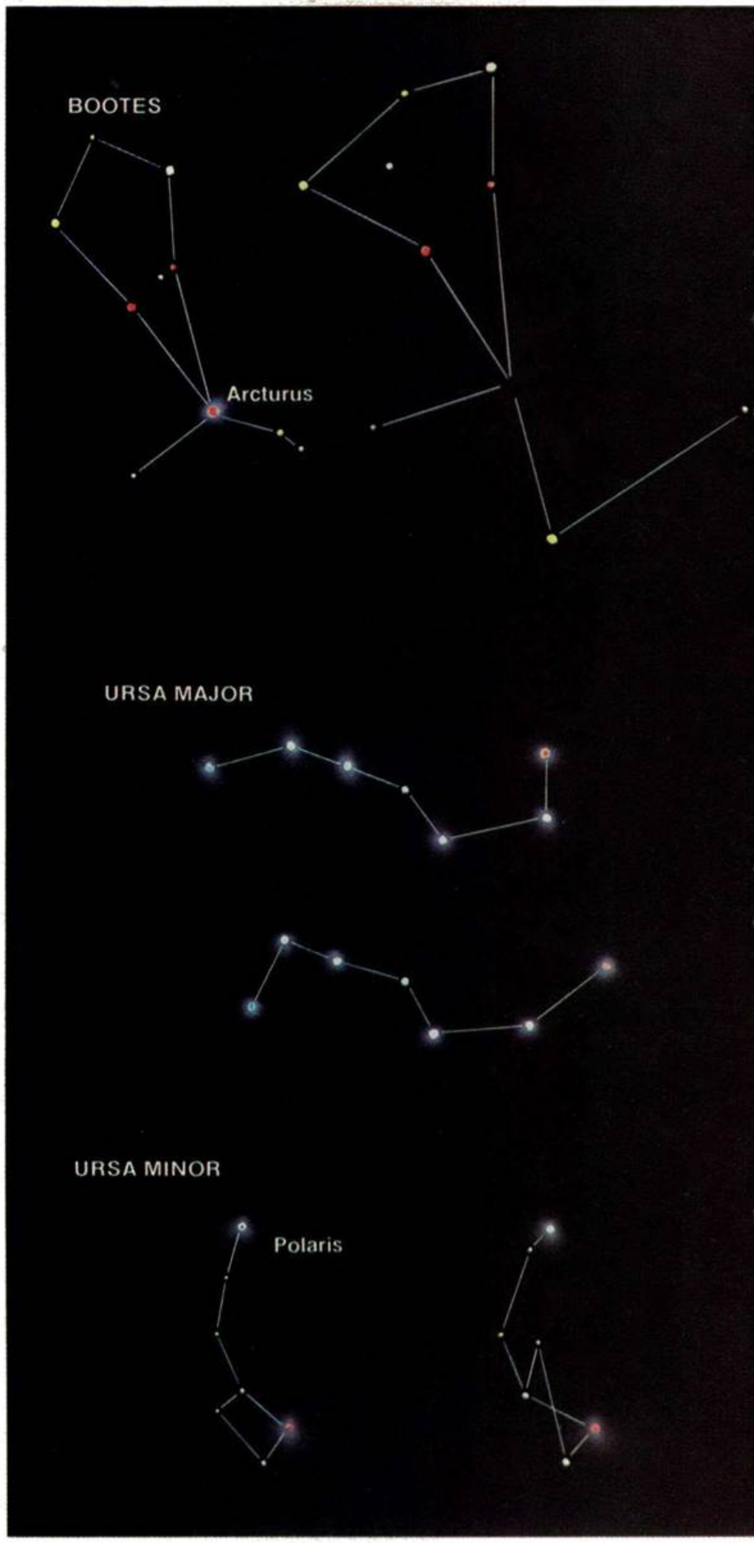
1. The star's *direction of motion.* The amount that a star's position changes depends greatly on which direction the star moves. Stars that are headed either directly toward or away from the sun have no proper motion at all, even if their actual velocity through space is high. In such a case, our line of sight is exactly along the star's path and it does not change its position in the sky. Stars approaching or receding from the sun at a very small angle will have a small proper motion. As the angle increases, so does the amount of change—a star moving at right angles to the sun appears to be traveling swiftly.

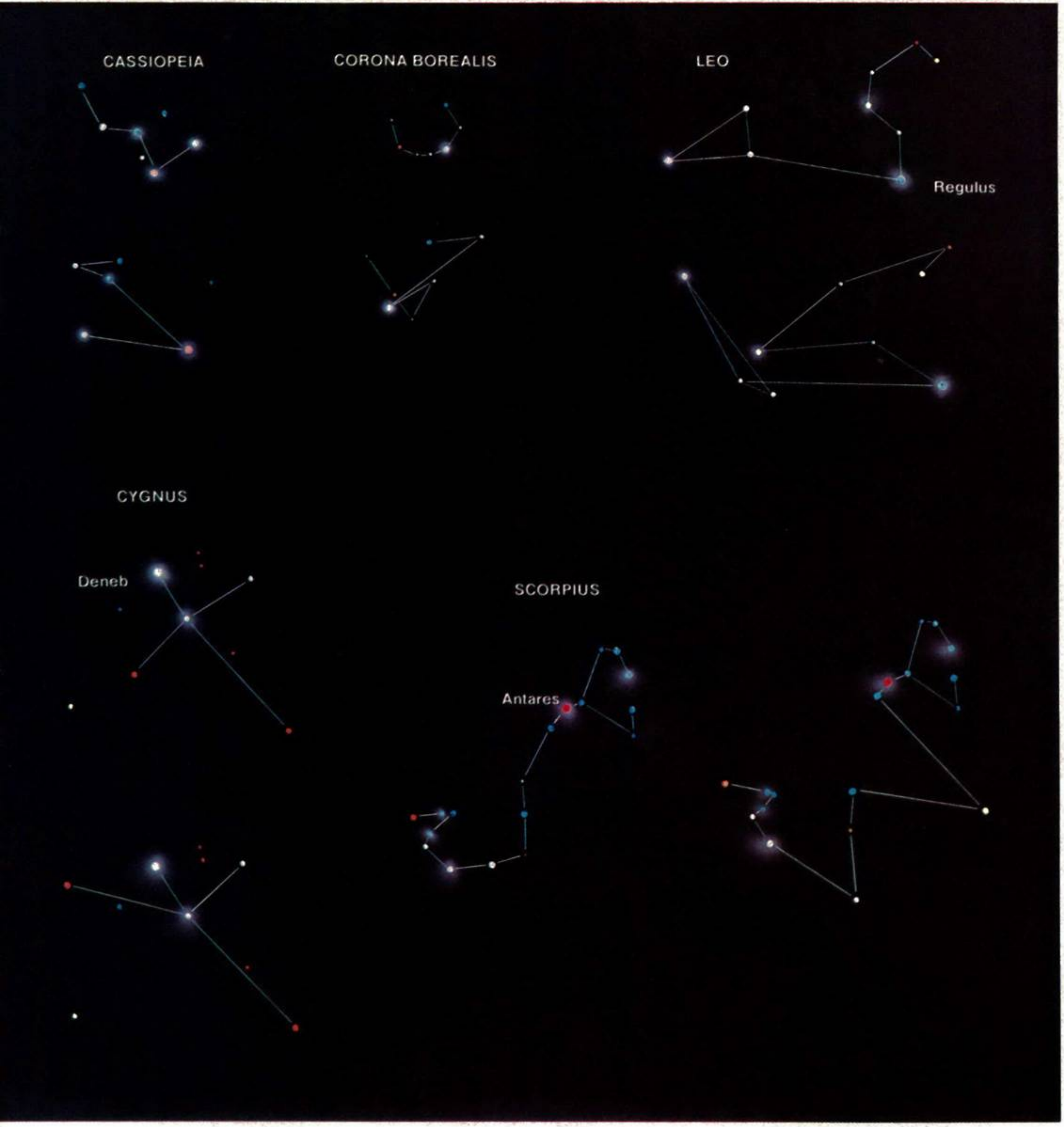
2. The star's *distance.* In most cases, the nearer a star is to the sun, the faster it will seem to move. If two stars with identical speeds, traveling in the same direction, are at different distances from the sun, the nearer will have the larger proper motion.

3. The star's *space velocity* (the true rate of speed of the star in space). Stars move at different rates: The sun has a space velocity of about 12 miles per second, while Arcturus's rate of speed is about 84 miles a second. The greater a star's actual velocity, the higher proper motion it will have (all other things being equal).

Various combinations of these different factors can produce some interesting effects. For example, a fast moving star moving in a direction almost exactly toward the sun will have a low proper motion compared to a relatively slow star moving at right angles to the sun. Or a slow, nearby star will change its position more radically than a very distant, very speedy star—similar to an auto on the ground that seems to move faster than a jetliner in the sky. On the other hand, a star's space velocity may be great enough that it can "outrun" a star that is nearer the sun. Such combinations are endless, and all of them are found somewhere among the stars.

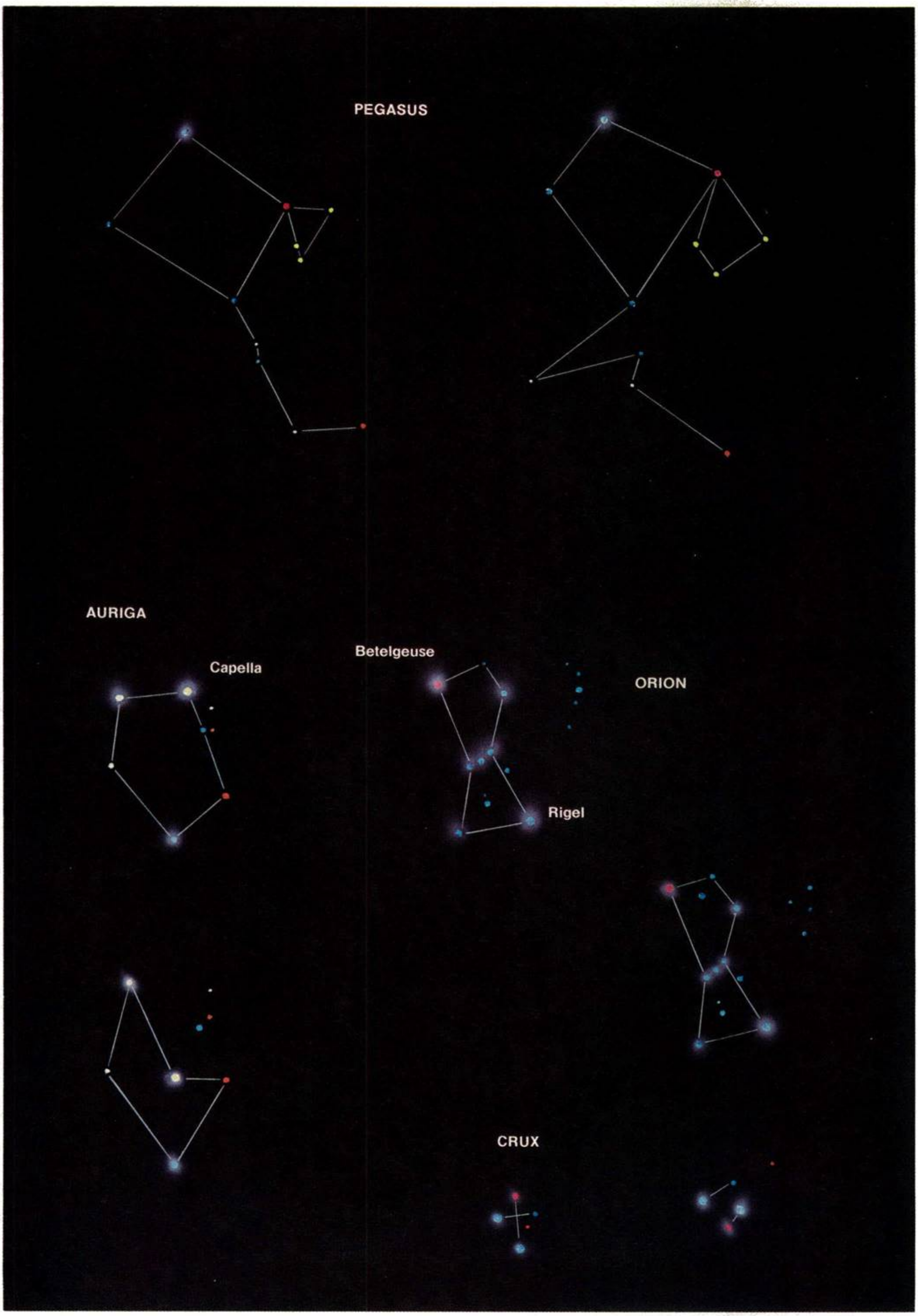
What practical knowledge does the measurement of proper motion give us? Often a star's proper motion can be used as a clue in finding its distance from the sun. And variations from a star's calculated path may indicate the presence of planets circling that star. We can predict the stars' positions in the sky for thousands of years into the future; or, alternatively, we can calculate their positions of the distant past. With current sophisticated equipment, scientists are able to measure a star's proper motion of a single year. Most stars have a proper motion of less than 0.1 second of arc per year; very few move at 1.0 second or greater—one of these is Arcturus. The star with the largest known proper motion is the famous Barnard's star, located in the constellation Ophiuchus. This star changes its position by about 10.2 seconds of arc every year.





The stars that form a constellation pattern are not fixed in their positions, as the ancients believed. Stars move rapidly through space, and our constellations are slowly losing their shapes as the stars change their positions. The diagrams on these pages compare the appearance of some constellations today with their appearance 100,000 years in the future. In some groups such as Scorpius, many of the stars belong to a large association, all traveling at the same speed and in the same direction; thus those constellation shapes will not change drastically. Other groups are going to pieces as their stars travel in all directions. Note expecially the disappearance of Arcturus from Bootes (upper left); Arcturus is one of the fastest moving of all bright stars. Artwork by Mark Paternostro.

Thus it is possible, solely by a process of multiplication, to find a star's approximate position for any year in the future or past. Of course, mere multiplication will not yield precise results. Stars with a high proper motion will also have a certain amount of angular velocity and move along a curving path. And the farther in time backward or forward one goes, the less exact the method becomes. Nevertheless, for simple purposes, it is an easily calculated indication of the changes our constellations


PEGASUS
AURIGA
Capella
Betelgeuse
ORION
Rigel
CRUX

will undergo—and, in fact, are undergoing right now. A well-known diagram, found in many popular astronomy texts, is a chart comparing the shape of the Big Dipper today with that of 100,000 years from now.

Though a long time in mankind's history, 100,000 years is only a grain of sand in the hourglass of universal time. Our constellations appear enduring, as they have been in their present forms since civilization began—but they are actually very transitory things. Our skies show a mere moment in the history of our galaxy, and 100,000 years will alter some of our constellations unrecognizably. So let's take a short look into the future and, with the help of the diagrams on pages 28, 29, and 30, view some of our constellations in 101,976 A.D.

Almost everyone knows how the Big Dipper is going to change. Five of its stars—Beta, Gamma, Delta, Epsilon and Zeta—are part of a large association, all the members of which are moving through space in the same direction and at the same rate of speed. The proper motion of these five Big Dipper stars is the same. Alpha and Eta, however, are not part of this group, and move in different directions. Thus our familiar Dipper is gradually falling apart. Yet these seven stars will still form a dipper of sorts in the future: Draw a connecting line between Eta and Gamma in the Dipper's new shape, and we have a dipper with two stars in the handle and five in the rather badly dented bowl.

The Little Dipper is also changing, but not in the same way as its larger counterpart. Only Eta has a very high proper motion, and since it is the faintest of the stars that comprise the Dipper, its motion may not be as noticeable. But Ursa Minor is slowly losing its own Dipper shape. Polaris, now located almost exactly on the circle traced out by Earth's precession, is leaving this circle and will eventually no longer be our North Pole star. Even by the time its turn comes up again, 25,000 years from now, it will be farther from the pole than it is today.

Cassiopeia provides an example of a constellation in which all the stars are rapidly flying apart from each other. Only Kappa will remain fairly stationary, and Cassiopeia's "W" shape will be completely altered—leaving behind a triangle of second magnitude stars. Eta is traveling so rapidly that it has moved off the page in our diagram. The reason for Cassiopeia's great change is the nearness to the sun of most of its bright stars, moving at right angles to it.

The constellation figures that we see in our sky will look much different 100,000 years from now — a long time for humanity, but only a moment in the history of our galaxy. In addition, the stars would have different appearances from a planet orbiting another star. There is nothing special about the constellations except that, at this moment, they are uniquely ours: From nowhere else in the universe could we see the same patterns. But even this distinction will be lost as the stars move and the constellations' shapes change. The stars of Orion, being very distant, will not move enough to destroy this most distinctive of all constellations; but Pegasus, Auriga and Crux are all undergoing various amounts of change and will be altered in the future. Artwork by Mark Paternostro.

A mistake has apparently been made in the diagram of Bootes—namely, the absence of Arcturus. But the only rush in which Arcturus has been forgotten is its own, for Arcturus is one of the fastest moving first magnitude stars. It will have traveled to the vicinity of the constellation Corvus 100,000 years from now, and will not be as bright. Arcturus and our sun are headed in opposite directions; at present, the two stars are only 32 light-years apart, but this distance will increase to 211 light-years by 101,976 A.D. This extremely rapid motion will leave Bootes a formless, nondescript constellation, bereft of its brightest gem.

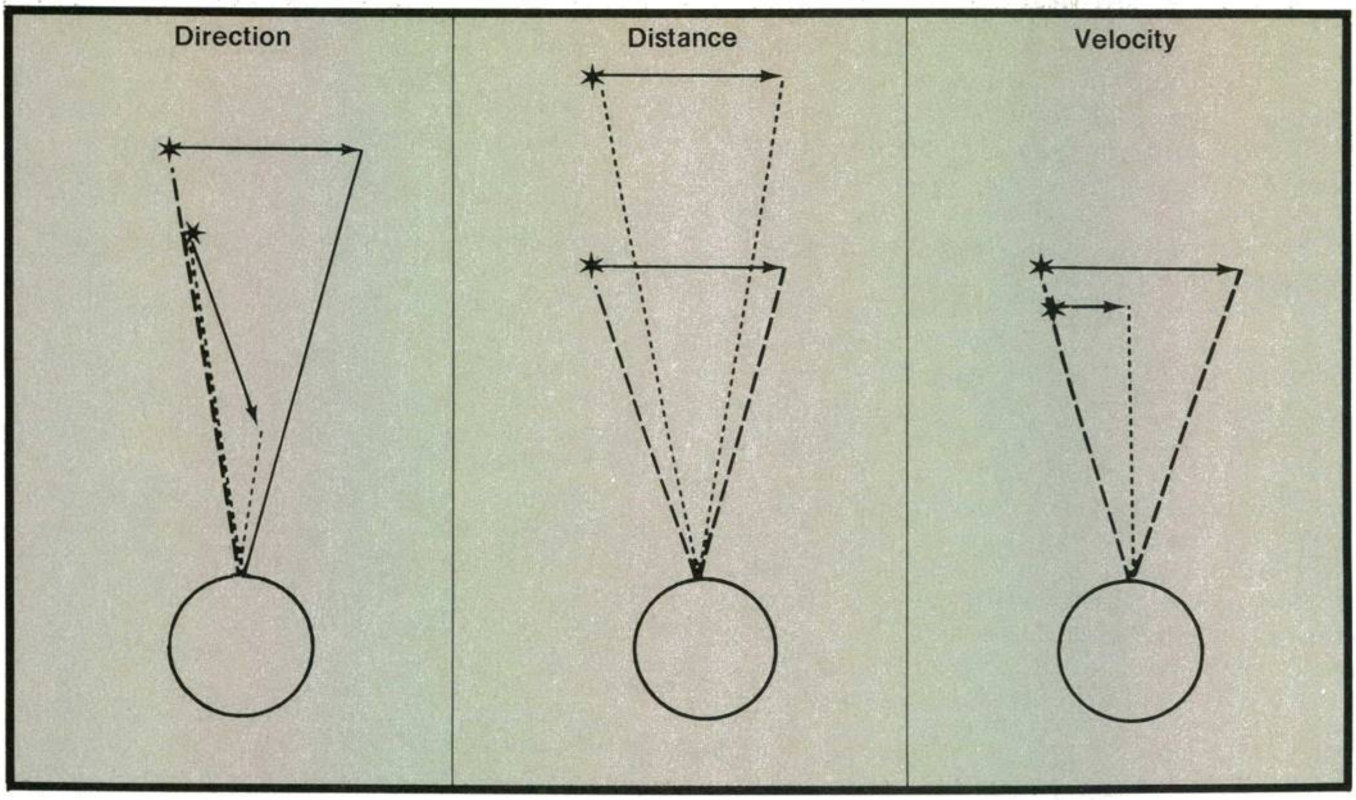
Corona Borealis is another constellation that is being ruined by the proper motion of its stars. In the future it will bear no likeness whatsoever even to the tiara it faintly resembles today. It will look somewhat like a bishop's mitre, however, and if the southern crown cooperates, perhaps a change of name would be in order.

Several stars in Leo— including Regulus, Denebola and Algieba (Gamma), its three brightest stars— are moving rapidly. The sickle is broadening as the triangle is getting narrower and more elongated. The resemblance to a lion that now exists in Leo will no longer be there. It is interesting to speculate on what new names might be given the constellations in the future—assuming that people are inspired to do so by changes in the patterns.

Deneb, the brightest star in Cygnus, is very far away from us—over 1,500 light-years. Its proper motion is therefore quite small, and Deneb will remain fairly stationary over the next 100,000 years. Of the stars in the northern cross, only Epsilon has a very high proper motion—but this will be enough to badly misshape it. Still, the case is not as bad here as it will be with the southern cross. The famous star 61 Cygni, one of the nearest stars to the sun, moves very rapidly and will leave Cygnus long before 100,000 years have passed.

Scorpius will not go to pieces as badly as some other constellations. A great many of the stars in Scorpius are part of another association, such as we noted in the Big Dipper. This whole region of the sky, in fact, contains a huge group known as the Scorpius-Centauri association, and these stars are all heading in the same direction. Only Epsilon and Eta do not belong to the association, and if the connecting lines to these two stars are removed in the future, Scorpius's shape will be as good as ever.

Although the Great Square of Pegasus will not be as close to a square shape as it is now, it will remain a distinctive landmark in the sky; Alpheratz and Gamma Pegasi will, unhappily, no longer point almost directly along the zero hour circle, but the four stars will still form a distinct grouping. The other stars in Pegasus will move in various directions, although Enif (Epsilon) will remain fairly stationary.



The amount of a star's annual proper motion depends on several factors. The diagram above shows (left) that a star approaching Earth will appear to move less than one traveling at right angles to Earth. At center, two stars with equal velocities lie at different distances; the nearer undergoes a greater change of position than the farther. The stars at right travel at different speeds, and one — although more distant than the other — has a larger proper motion. Diagram by David A. Schwartz.

Capella, in Auriga, is one of the closest of our first magnitude stars. It doesn't move nearly as quickly as Arcturus, but will shift its position far enough to considerably alter the pentagon that appears high in our winter skies. Nevertheless, if the connecting lines between these five stars are drawn differently, they will form an "X" that is, in its way, quite as noticeable as the pentagon. Perhaps this "X" will replace Cassiopeia's vanished "W" as the most distinct letter in the sky.

Orion is another example of a constellation that will be fairly stable through the centuries. Only Betelgeuse moves enough to be noticeable, and not so far that Orion's current shape will be much altered. Long exposure photographs of Orion reveal a faint nebulosity enshrouding almost all the stars in the region with its greatest condensation at the Orion nebula (M-42). All these stars are part of one huge association; even some of the stars in the shield (which actually are bright and seem faint only because they are distant) belong to this group. In fact, it is only the shield that will suffer with the passage of time, as some of its stars work their way eastward toward the giant figure to whom they belong.

Three of the four stars in Crux, the southern cross, share a common motion. The fourth (Gamma) does not, thereby breaking up this famous group about which so many effusive statements have been written. The name "southern trapezoid" just isn't as romantic.

Other changes besides those noted here are possible. Some faint stars may brighten as they approach the sun, while others fade as they recede. There will be many stars—even some of the brighter ones—that will cross borders into other constellations. Proper motion is bound to cause some problems of nomenclature. For example, since Arcturus will no longer be in the constellation Bootes, should astronomers of the future remove its designation as Alpha Bootis and rechristen it Alpha Corvi? If so, what will happen to the star which is currently known as Alpha Corvi? Should Arcturus be renamed at all? It will undeniably be the exact same star now known as Alpha Bootis. Might the borders of the constellations be altered to include all the stars that are currently within those boundaries? That might be difficult in this case, for the new border of Bootes would cut Virgo in half. Or should we remove all designations like Alpha, Beta, Gamma, etc., and rename all the stars the way we do asteroids? This might prove workable if Arcturus and other stars kept their present names — but if the list runs down, will we end up calling stars "Albert" or "Fred"?

All such questions may be academic, for if humans continue to progress and move out into space, the ancient constellation patterns may well degenerate into mere curiosities — relics of a long-gone past on the museum known as Earth.

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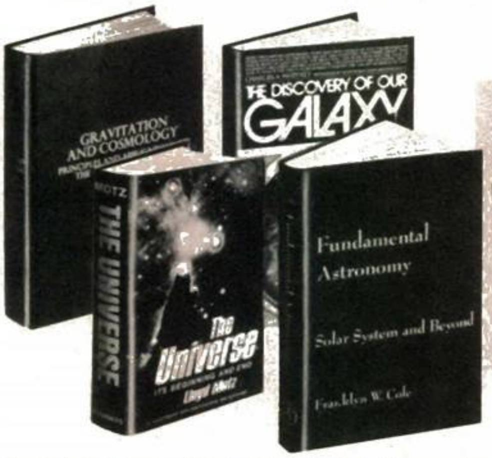

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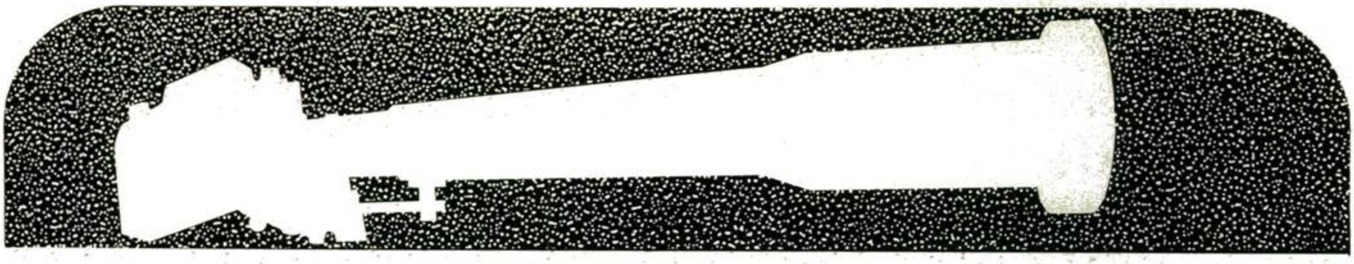


PHOTOGRAPHY IN ASTRONOMY

Astrophotography...

In Spite of Myself

"If anything can go wrong, it will!" — Murphy's Law

by

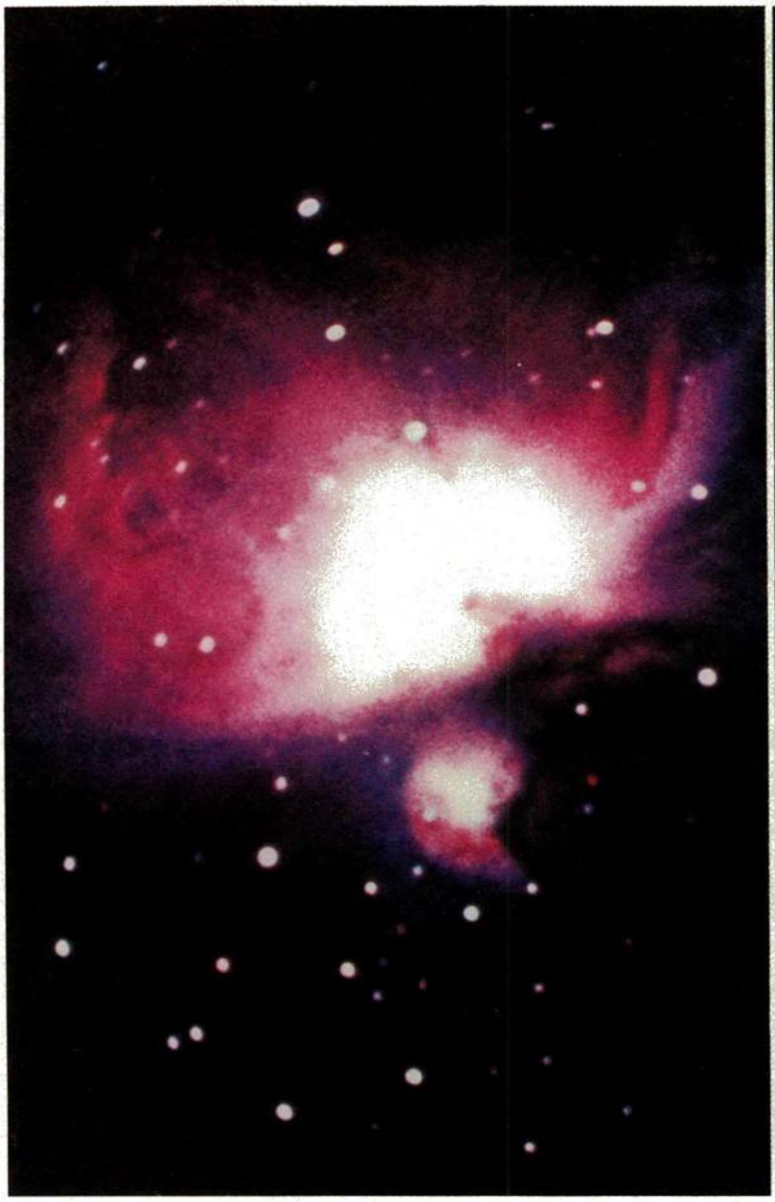
David Healy

Recommended Exposure Times for Deep Sky Objects

Object		103aF	GAF 500
		Exposure Time at f/5	
M-31	Andromeda galaxy	60 min.	80 min.
M-33	spiral galaxy (Triangulum)	60 min.	80 min.
M-45	Pleiades (Taurus)	40 min.	60 min.
M-42	Great Nebula in Orion	10 min.	15 min.
NGC-2024	emission nebula (Orion)	40 min.	60 min.
M-35	open cluster (Gemini)	30 min.	40 min.
M-13	globular cluster (Hercules)	7 min.	15 min.
M-8	Lagoon nebula (Sagittarius)	15 min.	20 min.
		Exposure Time at f/10	
M-57	Ring nebula (Lyra)	40 min.	60 min.
M-27	Dumbbell nebula (Vulpecula)	40 min.	60 min.

Most astronomy books and magazines — including ASTRONOMY — are filled with exquisite celestial photographs; the accompanying captions convey the ease with which these photos were produced. In fact, there have been so many advances during the last few years — both in telescopes and

The entire constellation Orion is captured in the photograph at right. A 10 minute exposure on GAF 500 film reveals nebulosity and faint stars that are invisible to the naked eye. Constellation photography such as this is made possible by the piggyback method: The camera is mounted on the telescope tube and guided, permitting long exposures. Here, a Miranda Laborec equipped with a 50mm f/1.8 lens was used. Photograph by David Healy.



film — that color photographs any observatory would have been proud of as recently as 15 years ago can now be taken by astronomy enthusiasts equipped with a six or eight inch telescope and inexpensive film. This article, however, is dedicated to the thousands of enthusiasts who do just what I do: crash around in the dark and waste film by the foot before getting a presentable photo. You see, I'm convinced that Murphy must have been an astrophotographer.

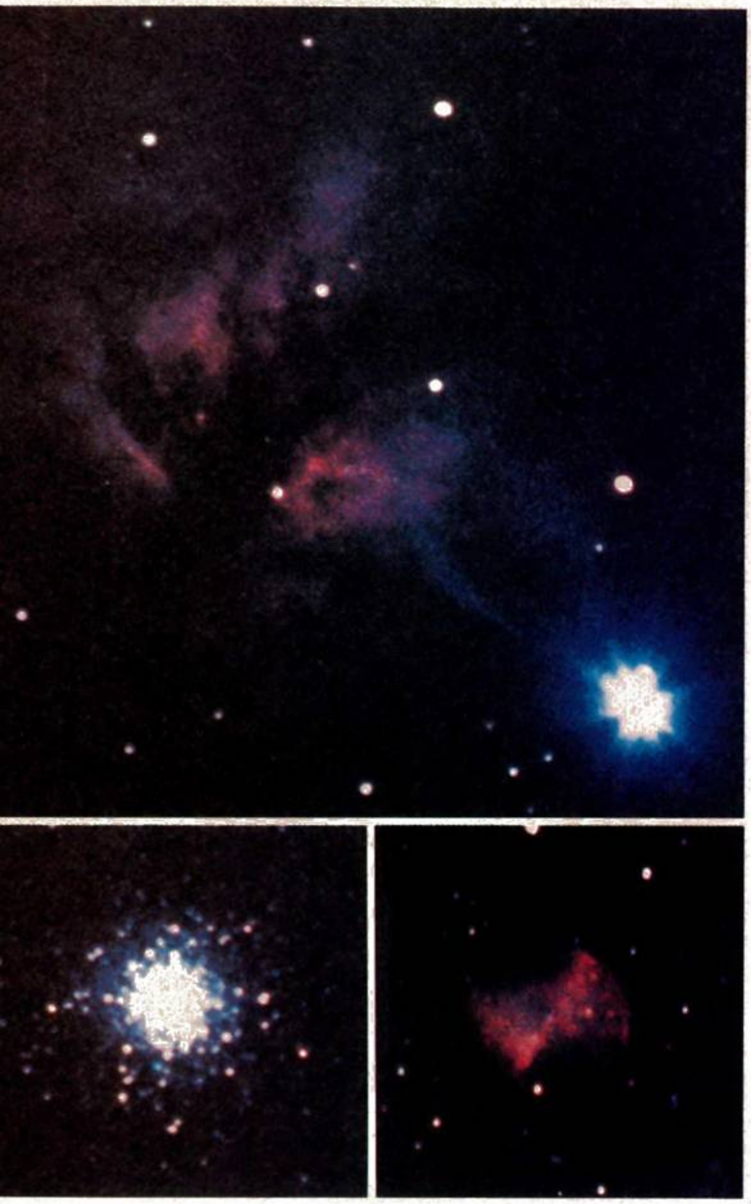
I think the reason Murphy haunts amateur astrophotography so much is that most of us are trying to operate complex equipment in the dark while fighting fatigue from the day's normal activities. I know that I have to be on my guard every minute; as soon as things are going well and I start to relax, Murphy pounces and I ruin another photograph. But when I finally manage to outwit Murphy and get a good picture, all my crashing and fumbling is worth it.

As encouragement to those who are just beginning, my first deep sky photograph of the Andromeda galaxy (M-31) has to be the worst photograph ever taken by anyone, at any time, anywhere. By my count, there are *at least* six major technical errors in the picture — any *one* of which could have ruined it. Sky conditions were inappropriate for deep sky photography; my telescope wasn't polar aligned; I guided incorrectly and used the wrong film; the exposure was too short, and the telescope became fogged with dew during the exposure.

Let's take a closer look at these six mistakes, one by one. If you're a beginner, maybe it can save you a few hours of fumbling and several yards of film.

Sky Conditions

The spiral arms of M-31 are quite faint—a good deal fainter than the illuminated smog in the New York area's night sky (little wonder they were nowhere to be found on my first photo). The best color photos must be taken through dark skies, well



Several of the most often photographed deep sky objects are shown in these pictures. At far left on the opposite page, a 15 minute exposure of the Orion nebula (M-42) reveals faint streamers of gas extending from the main body of the nebula. A much longer exposure — 1 hour 10 minutes — is required to show structure in the spiral galaxy M-33 in Triangulum. Near Zeta Orionis, one of the stars in Orion's belt, is NGC-2024 (this page, top), another concentration of the nebulosity that enshrouds the entire constellation; this is a 40 minute exposure. The Dumbbell nebula (M-27) in Vulpecula is seen at lower left in a 20 minute exposure. This is one of the brightest planetary nebulae in the sky, as M-13 (lower right) in Hercules is one of the brightest globular clusters. A 15 minute exposure of the cluster partly resolves its center. All photographs were taken on GAF 500 film through a Celestron 8 at f/5. Photographs by David Healy.

away from "Aurora Commercialis". But you can get reasonably good photos of some brighter deep sky objects — such as the Great Nebula in Orion (M-42) or the Hercules globular cluster (M-13)— from all but the most heavily populated urban areas. For those city dwellers who prefer black and white photography to color, one alternative is red-filtered black and white photography — it really works! The red filter sharply cuts down sky fog and light pollution, enhancing contrast between a faint object and the sky background. (See "A Red Window to the Sky", ASTRONOMY, February 1975.)

Even if you live away from the city, good seeing (absence of atmospheric tremor) isn't nearly as critical for success in deep sky work as it is in lunar or planetary photography. It certainly doesn't hurt, however.

Polar Alignment

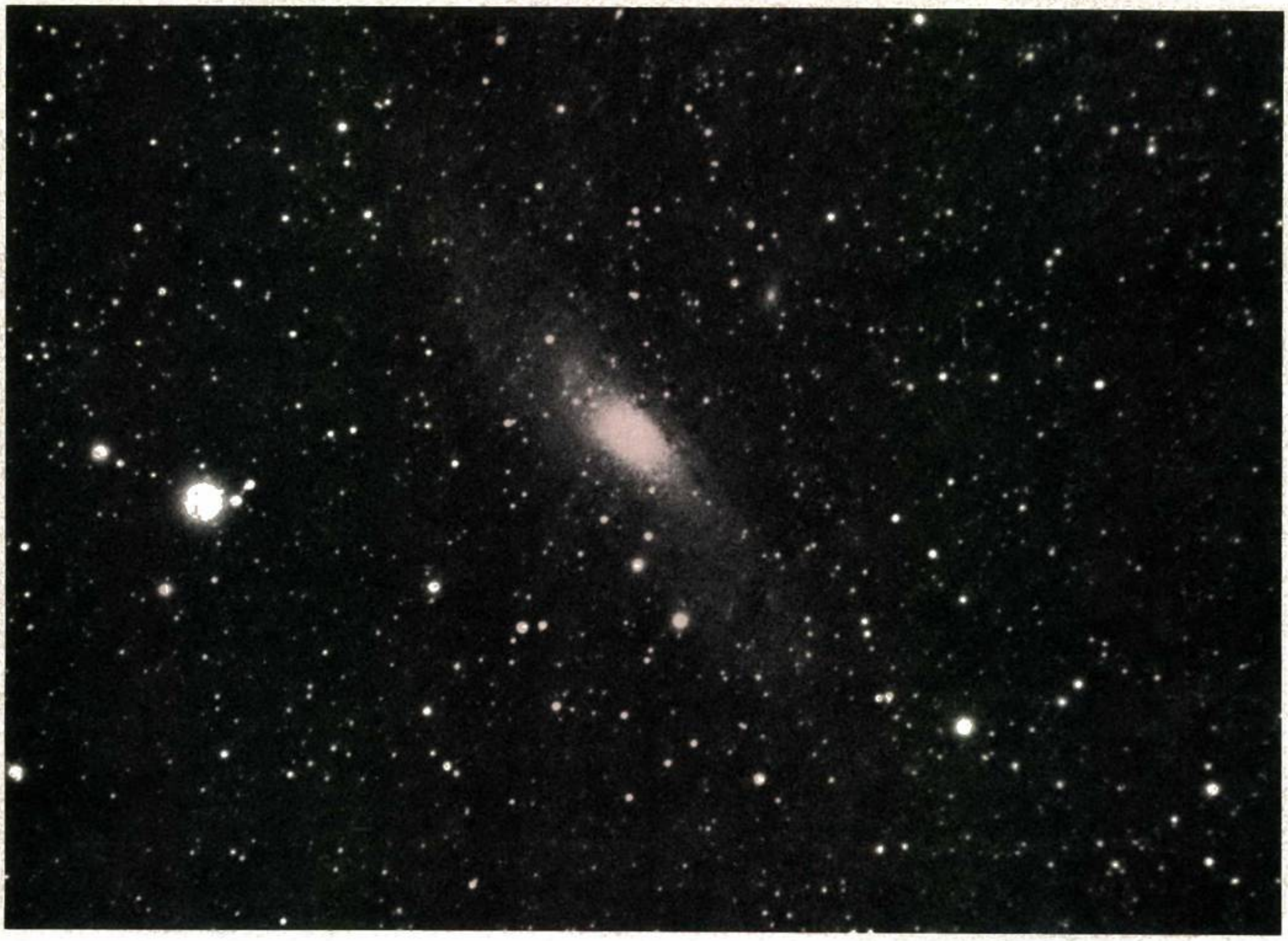
Good polar alignment, a must for deep sky photography, has been my worst mechanical problem. Murphy always crops up sooner or later while I'm trying to follow the methods suggested in the instruction books that came with my telescopes. I've sidestepped Murphy as best I can by developing my own routine, which combines features from a number of different systems I've tried.

Your sky probably gets dark enough for you to find Polaris and either the Big Dipper or Cassiopeia. An imaginary line from Epsilon Cassiopeiae (the easternmost star in the "W"), or from Eta Ursae Majoris (the star at the end of the Dipper's handle), through Polaris comes very close to intersecting both the pole star and the north celestial pole (NCP) itself. At present, the NCP is located 52 minutes of arc from Polaris, in the direction of the Big Dipper.

I take advantage of these convenient reference stars to align the polar axis of my telescope as precisely as possible on the NCP. After leveling the tripod and setting the declination scale to 90 degrees, I turn the telescope in right ascension until the declination axis is aligned with the Eta-pole-Polaris-Epsilon line. Then, I orient the telescope so that Polaris is visible in the finder. (Be sure, incidentally, that the finder itself is aligned with the telescope.)

My 6x30 finderscope has, by convenient coincidence, a field of view about 3½ degrees in diameter — or 1-3/4 degrees (105 minutes of arc) from the crosshairs in the center to the edge of the field. Thus the angular distance between Polaris and the NCP — 52 minutes of arc — is almost precisely half the distance from the field's center to its edge. Keep one of the crosshairs parallel to the declination axis, and your telescope will be polar aligned when Polaris is on that crosshair halfway between the field's center and edge. Remember also that the typical finder inverts the view; when you use Epsilon Cassiopeiae as a reference star, the Epsilon-Polaris-pole lineup will be reversed in the finder.

If you're in Murphy's clutches as much as I am, your careful alignment will deteriorate as one of the tripod legs sinks deeper into the mud than the others. Or, as you move around in the dark, you'll trip over the tripod and shift it three degrees in azimuth (not to mention turning an ankle). At



The region of Orion's belt is very rich in bright stars and nebulosity. The top photograph on the opposite page shows this area; note especially NGC-2024 near Zeta Orionis (another photograph of this nebula appears on page 37) and the Horsehead nebula south of Zeta. A 200mm f/3.5 lens was used for this 40 minute exposure obtained with the piggyback guiding method. The Lagoon nebula (M-8) in Sagittarius is one of the most prominent emission nebulae in the sky. Bright stars and dark knots can be detected in this 19 minute exposure. The North America nebula in Cygnus is an object that is almost invisible optically; its distinctive shape is best seen photographically, as in this 10 minute exposure. The Ring nebula (M-57) in Lyra is another bright planetary nebula with a faint central star; this hour long exposure was taken through a Celestron 8 at f/10. Nebulosity around Gamma Cygni is seen against the background of the Milky Way in a 10 minute exposure. All the pictures on the opposite page were taken on GAF 500 film and (except where noted) through a Celestron 8 at f/5. The black and white shot above of the Andromeda galaxy (M-31) was made on 103aF film through a 200mm f/3.5 lens; this is a 15 minute piggyback guided exposure. Photographs by David Healy.

home, I've solved the mud problem by pouring a level concrete slab for the tripod. I've yet to figure out a way to bring the slab on field trips.

Setting Up and Guiding

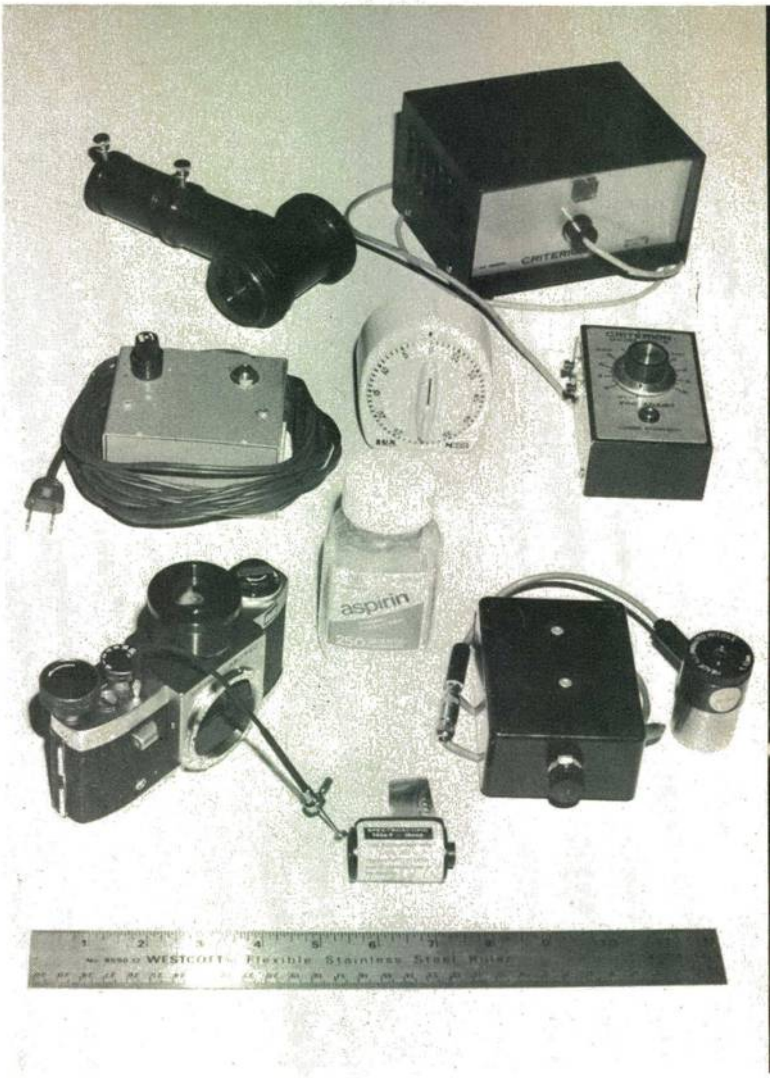
After I'm finished aligning, I center the telescope on a bright star in the same area as the object I want to photograph. I look up its coordinates and set the right ascension circle to the star's celestial longitude. Before moving on, I focus the camera on this locator star.

A great Murphy-thwarter at this critical stage is a 35mm single lens reflex camera that has a clear focusing screen in its viewfinder, with a ground-glass spot at the screen's center (the Miranda Laborec is a good example). The standard ground-glass screens on most cameras will not allow precise enough focus on dim stars. When you focus, use the ground-glass spot, because Murphy will not let you focus accurately on a clear screen. My first photograph of the Ring nebula (M-57) looked like a doughnut shop, since everything in the picture looked like the Ring nebula. This effect, of course, was caused by the out-of-focus camera picking up the scope's secondary mirror obstruction.

Before taking your first photograph, it's a good idea to practice guiding on a bright locator star. For instance, if Vega is your locator star, try guiding your scope on Vega before moving on to an eighth magnitude star you can hardly see through the crosshairs. Once focused on the locator star, move the telescope until you read the desired object's coordinates on the setting circles, allowing for any error in the declination reading. If Murphy's law is operating, there will be absolutely nothing in view — but you can usually find your object by sweeping around a bit.

The next step is to locate a suitable star for guiding. There are plenty of stars bright enough to be seen, but having them correspond to the field you want to photograph is another matter entirely.

Murphy's law states, "If anything can go wrong, it will." In the attempt to counteract this law, many astrophotographers use some or all of the equipment shown in the picture at right (or similar instruments). These include (clockwise from bottom left): Miranda Laborec SLR camera, heated dewcap power supply (Roger Tuthill), off-axis guider with telecompressor lens (Celestron), oven timer, variable speed drive with control box (Criterion), illuminated reticle eyepiece and battery pack (Meade Instruments), Kodak 103aF black and white film — and, when all else fails, aspirin. With the help of some of these instruments, Murphy was avoided and the photograph at far right was obtained. This one hour exposure of the nucleus of the Andromeda galaxy (M-31) was taken through a Celestron 8 at f/5 on Kodak 103aF film. Compare this picture with the one of the entire galaxy shown on page 39. Photographs by David Healy.



Insert a low power eyepiece (about 40 power is sufficient) into your guidescope and find a star as close as possible to the center of the field of your photograph. If your guidescope is a ring-mounted refractor, you can make fine adjustments to align the star on the eyepiece's crosshairs. (Illuminated crosshair eyepieces, though expensive, are a great help here.) Next, switch to a high power guide eyepiece and fine-tune your guidescope until the star is directly on the crosshairs. This latter adjustment is a difficult one to make; it's a lot easier to simply angle your main tube until the guide star is properly located. This will off-center the object you want to photograph in the field, but the picture can be properly centered during the printing process. Besides, the fewer fine adjustments Murphy has to interfere with, the better your chances are.

By now you've probably noticed that gadgetry proliferates in deep sky astrophotography, and each gadget comes equipped with its very own, fresh, alert Murphy ready to do you in. Nevertheless, another essential gadget is the drive corrector, or variable speed drive. This lets you make guiding corrections in right ascension by changing the speed of your telescope's drive motors. As for declination corrections, the better the polar alignment, the fewer these will be; if absolutely necessary, it's best to equip your telescope with slow motion control knobs. It's physically impossible to keep the guide star exactly on the crosshairs for the duration of the exposure, and it isn't really necessary. If the power of your guidescope eyepiece is five times the telescope's focal length, small deviations of the guide star from the crosshairs will be too small to affect your picture.

Useful miscellaneous accessories include a locking cable release (the best means of keeping the shutter open during an exposure) and a trusty oven timer. The latter is a great gadget for astrophotographers because it ticks while it's going and rings when time's up. Otherwise, Murphy will inevitably make the scope drive hiccup while you're checking your watch.

Films

The most important advice about film for astrophotography is: Make sure there's some in the camera. During one of my field trips, there wasn't —not Murphy's fault, this time, but John Barleycorn's—and it proved rather embarrassing.

Next, use the correct film for the object you want to photograph. Even if I had done everything else properly on my first M-31 shot, the combination of a 20 minute exposure at f/10 and High Speed Ektachrome film (pushed to ASA 400) would have doomed it. I've found Kodak color film largely ineffective for long exposures of faint objects, due to reciprocity failure. In my experience, High Speed Ektachrome might as well be ASA 0 for all but the brightest objects and the lowest f-ratios. On the other hand, I've totally rejected the idea of chilling Ektachrome — this would present Murphy with a chance to give me frostbite.

All of my best deep sky color photographs have been taken on GAF 500 film — it's quite fast and suffers only moderately from reciprocity failure. Its chief fault is graininess, which limits enlargeability. But if you're not too fussy about fine detail, you can blow up half a 35mm slide to 8 x 10 size and have a perfectly presentable photo.

A black and white, finer grained film with little apparent reciprocity failure is the Kodak spectroscopic film 103aF. This film puts many galaxies and

faint nebulae — difficult or impossible to photograph with other films—within the astronomy enthusiast's reach. Kodak 103aF is sold only in bulk, but you can buy 36-exposure rolls from Optica b/c Company in Oakland, Calif., for about $7 a roll. The film's ASA rating is about 320, but for 30 to 60 minute exposures of dim objects, it's effectively almost twice as fast as GAF 500 because of its low, low reciprocity failure. When you're ready to process the film, you (or your photo lab) should develop it in D-19 for four minutes at 68 degrees Fahrenheit for best results.

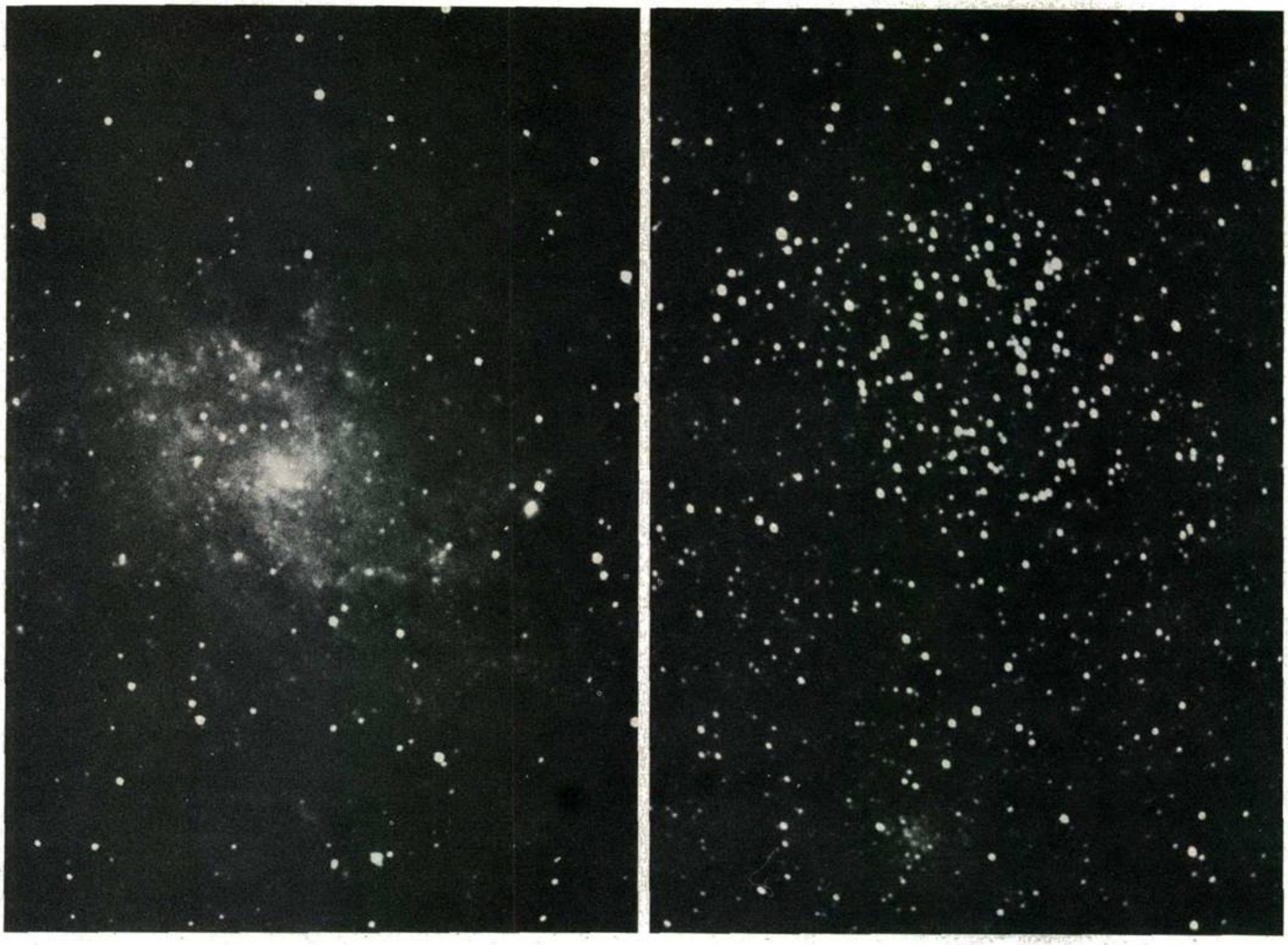
Focal Ratios and Exposures

You really can't do too much deep sky photography when you're working with the high focal ratio of most telescopes' prime focus, due to the long exposures needed (hence more time for Murphy to creep up on you). My most rewarding shots of large areas of the sky were made at f/1.8 to f/3.5. Simply, I used my telescope as an oversized guider for the conventional camera-lens setup by using the piggyback method (mounting the camera on the scope for guided exposures). At f/1.8, however, exposures as short as six minutes on 103aF or 10 minutes on GAF 500 begin to pick up sky fog, even in dark sky areas.

Most of the exposure times I've seen suggested for deep sky objects are too short. In the table on page 34, I've listed exposure times I've had success with (and would recommend) for a few of the best known and most often photographed objects. The list presumes dark sky conditions and a focal ratio of no more than f/5. I've also added a couple of fairly bright nebulae that I've been able to shoot at f/10 (which means you should have even better luck if your scope is f/7 or f/8).

Dewing

Long before that notorious first photo of M-31 was completed, the front corrector plate of my catadioptric telescope became completely fogged with dew (about as effective for photography as solid overcast skies). Refractor owners will have the same problem with their objective lens. This dampness on clear evenings is quite prevalent where I live, and I've had to find several methods of solving the problem. The first — and worst — is simply to wipe it off. The dew will be back shortly, though, and if you scrub the lens enough you'll eventually scratch it badly. A dewcap helps; it should be at least as deep as your aperture is wide, and preferably deeper. But on some damp nights, particularly if you're



Compare this photograph of M-33, the spiral galaxy in Triangulum, with the picture on page 36. This is a one hour exposure on Kodak 103aF film. M-33 is one of the most difficult deep sky objects to observe satisfactorily; because it spreads over a relatively large area of the sky, it has low surface brightness. Long exposure photographs reveal much more detail than can be seen visually through the telescope. The picture at right is a 30 minute exposure on 103aF of M-35, a prominent open cluster in Gemini, along with its small "companion" cluster NGC-2158. Photographs by David Healy.

photographing an object near the zenith, an ordinary dewcap is not enough. I've acquired Roger Tuthill's No-Du heated dewcap. A nichrome wire embedded in it raises the temperature of the front lens a few degrees. This works on all but the dampest nights. For those who, unlike myself, are electrically competent and unafraid of self-electrocution, a homemade objective heater could represent a substantial savings.

My final solution to the dewing problem is a hair dryer. Its hot blast quickly dries the optical surfaces of my telescope, sometimes warming them enough that they stay dry for 20 minutes or so. When dewing is so bad that I'm constantly drying off not only my lens but also my eyepieces, finder, camera and contact lenses, it's time to head indoors.

Paperwork

Murphy being a gadget-crazed gremlin for the most part, the only thing he neglected to screw up on my first deep sky photo was my written record of it. You must jot down details — equipment, exposure, film, sky conditions, etc. — at the time you photograph. Otherwise, Murphy will blot from your memory whether your exposure was (for example) 11 minutes at f/5 or five minutes at f/11. You can't correct mistakes at your next session unless you know what you did wrong the first time. It's also essential to program what you want to shoot, and how, before you actually begin. Besides, it's more fun to work from a plan. I have a wad of paper about an inch thick of photography programs and notes (about a year's worth). It's terribly boring reading for anybody but myself, but in the long run it makes for better pictures.

Murphy will always present a problem to astrophotographers, but maybe this advice will help you circumvent him and give you a better ratio of good photos than I've had. If you get even one good picture from every seven attempts, you'll have successfully conquered Murphy's law. Then all you'll have to worry about is Murphy's *second* law, which goes: *"If anything cannot possibly go wrong, it will anyway!"*

David Healy, a securities analyst for a New York stock brokerage firm, has been a photography enthusiast for 10 years. His most recent activity in astronomy has allowed him to combine both interests in astrophotography.

Occultation Photography

by

Richard Berry

Mars' occultation of Epsilon Geminorum is the most exciting astro-event of the year, but it won't be easy to catch on film. You'll really have to be on your toes, and even then you'll be gambling with clouds. But for such a rare event, it'll be worth a try.

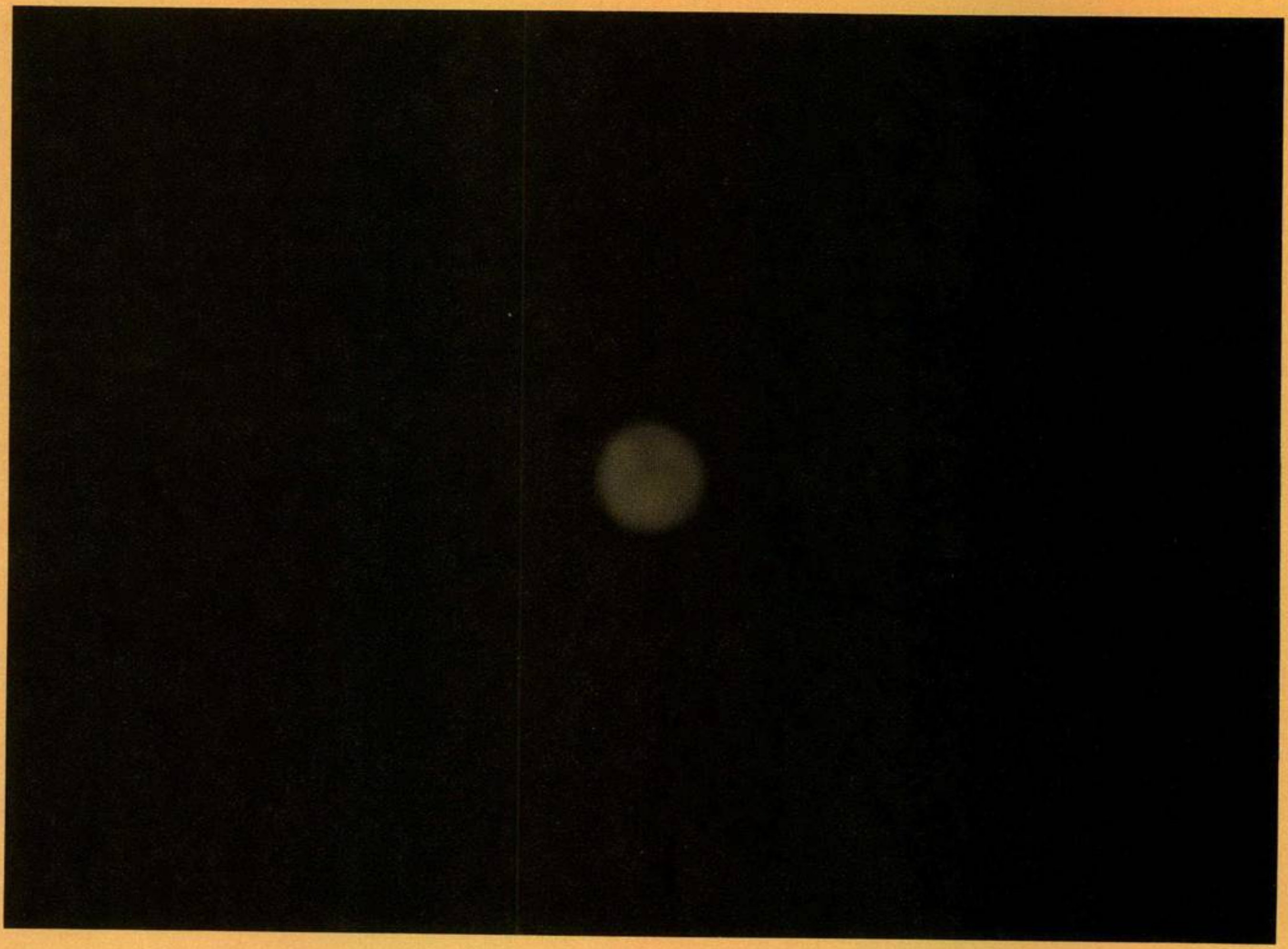
If you don't own a telescope, you can still capture Mars' approach to Epsilon with any 35mm camera. A series of pictures each night for two weeks before and after could show it well. Both Mars and Epsilon are bright enough to show up in an unguided 10 second exposure. You'll be amazed to see how fast Mars is moving–just about a full moon diameter each night.

If you've got fancier camera equipment, the rule is: Use your longest telephoto lens. On the night of the occultation, using a 200mm lens, you may be able to show Mars and Epsilon as separate objects as little as 10 minutes before and after Epsilon is covered. With your camera at the first focus of a 2.4 or 3 inch refractor (see "Astrophotographic Routes", ASTRONOMY, May 1975), you may be able to record Epsilon and Mars as separate objects until two or three minutes before contact — with the telescope drive on, using exposures of about one second. The images will be tiny and extremely close together.

How do you know which exposures will be best with small telescopes and cameras? The best way to find out is to run trial shots in advance of the event. Try exposures ranging from 1 to 10 seconds, get them processed, and choose the shortest exposures that will show both Epsilon and Mars.

The fact is, you'll need a big telescope — six inches or more aperture — to really photograph the occultation the way you'll see it. You'll have to use eyepiece projection to show the disk of Mars. How big should the image be? The bigger the better: With an eight inch scope used at f/100 (about 800 inches effective focal length), Mars will be only 1/40 inch on the film, and if the air is ideally clear and steady, Epsilon will be about 1/300 inch! The chance of recording surface detail on Mars is low, unless you have a 12 inch or larger aperture scope.

Eyepiece projection is the favorite method of planet photographers for enlarging a small planetary image onto film. Just as your telescope can "project" an image of the sun, it will project an image of a planet too, with an eyepiece acting as the projection lens. You'll need a homemade or commercial eyepiece projection adaptor, as well as your camera, telescope and eyepiece, just as you would for any lunar or planetary high resolution photography. You can expose using the camera's shutter, but that may shake the telescope as the shutter is tripped. The "black hat" trick pretty much eliminates camera



Mars will look much smaller on April 7 than it was when this picture was taken, six days after opposition in December 1975. At that time, Mars' diameter was 16.1 seconds of arc; during the occultation, it will be 6.4 seconds of arc. This photograph was taken with a Celestron 8 using eyepiece projection from a 12.5mm eyepiece. The effective focal ratio was f/98; the exposure was 1/2 second on High Speed Ektachrome. Photograph by Steve Reed.

vibration. To do it, focus the scope carefully, cover the aperture with a black hat or sheet of black cardboard, and open the camera shutter for "b". When all vibrations have died, uncover the telescope for your exposure, and close the camera shutter. You should practice ahead of time by taking pictures of both Mars and Epsilon; you will then learn the best exposures for both, and be in practice for the big event.

If you've never tried eyepiece projection pictures of a star before, you'll get excellent practice with double stars like Mizar. You'll be surprised how bright they look in the viewfinder, and amazed that they often need less exposure than the planets. If the air is steady, Epsilon and Mars will record in just about the same exposure. Mars will be orange-red, and Epsilon, a G8 supergiant, will be yellowish.

You'll need to find Mars about a half hour ahead of time if you want to take a series of pictures. If you live in the Midwest or West, the sky will be pretty bright, making Mars difficult to find. See Gazer's Gazette for details.

An excellent series of pictures would show Mars and Epsilon every minute for 10 minutes before and after the occultation. Of course, a few extras just before and just after the occultation, when Epsilon is extremely close to Mars, would be very exciting. If you're really lucky, you might make an exposure just as Epsilon is occulted. To choose the best moment for such an exposure, watch the occultation through your camera—unless you use the black hat method, where you won't be able to see through the camera. You might arrange to watch the event with a friend, who could let you know just the right moment for the exposure.

What films will be best? In this case, the faster ones: Tri-X or Ilford HP-4 in black and white; High Speed Ektachrome, Fuji R-100, GAF 200 in color. GAF 500 will be too grainy, but if you have shutter vibration problems, it might let you use a shutter speed fast enough to avoid the shutter recoil.

What exposure should you use? Again, a trial run ahead of time is the best solution. A good starter for eyepiece projection at f/100 is 1/2 second on High Speed Ektachrome, 1/4 on Tri-X or GAF 500, and one second on the slower films.

So even though it won't be easy, Epsilon Geminorum and Mars are putting on a first rate show for you, and you can get an exciting record of this rare planetary "wipe-out".

ASTRO-NEWS

Latest News From the World of Astronomy

Solar Pulsations Detected; Throws Kink in Theories

Oscillations of the sun, similar to the pulsations of a variable star, have been detected in two types of solar observations by scientists in the United States, the Soviet Union and Great Britain.

The observational results contradict the established view that the sun is a stable star radiating energy primarily by the fusion of hydrogen nuclei in its core. The cause of the oscillations is not yet known.

Science magazine recently referred to the observed situation as "a crisis" in efforts to understand stellar evolution and energy generation. These theories, applied to stars throughout the universe, rest heavily on observations of Earth's closest star, the sun.

Early reports of rapid solar oscillations were made by Dr. Henry Hill and his research group at the Santa Catalina Laboratory for Experimental Relativity by Astrometry at the University of Arizona. Hill's experiment was originally designed to measure the precise shape of the sun as part of a test of Einstein's special theory of relativity. However, as observations were being analyzed, unexpected periodic variations in the sun's disk were discovered.

Previous observers had missed the oscillations because the "shivers" amounted to less than 1/10 second of arc and were blurred by the seeing. Hill's technique allowed him to measure the sun's diameter with extreme precision. Solar oscillations were found to have up to 50 minute periods. Hill's measurements did not provoke speculation that current models of the sun were grossly in error.

Soviet scientists at the Crimean Astrophysical Observatory reported (in the British journal **Nature**) the detection of stable solar pulsations with a period of 2 hours 40 minutes ±30 seconds. Dr. Andrei Severny, director of the observatory, and two colleagues wrote that the simplest explanation for the observation is that the oscillations consist of regular expansions and contractions in the sun's shape. The slow rate implies an internal structure of the sun incompatible with that assumed for energy generation by fusion.

(The observed period is almost identical to one predicted by Ritter's formula for radial pulsations in a homogeneous sphere.)

An extravagant solution offered by the Soviets is that accepted methods of solar energy production by nuclear reactions "are not responsible for energy production in the sun."

The Russian scientists could not discriminate between expanding or contracting solar pulsations and those involving a change in shape. They measured a to-and-fro motion of about five miles.

Three British physicists reported in the same issue that the surface of the sun seemed to be moving toward and away from Earth at a cycle of 2 hours 39 minutes ±2 minutes. The primary objective of the British experiment (conducted at the Pic du Midi Observatory in France) was to find gravitational redshifts in the solar spectra.

Sun *continued on page 47*

NASA Gives Uranus Mission Go-Ahead

Alternate plans to send one of the two Mariner Jupiter/Saturn spacecraft beyond the ringed planet to Uranus have won NASA approval.

NASA previously withheld funds earmarked for the Uranus mission due to severe budget restrictions imposed by Congress. However, Jet Propulsion Laboratory engineers devised a way to take a Mariner scheduled for a Saturn encounter and give it the extra capacity to go on to Uranus.

If successful, the spacecraft should fly by Uranus sometime between November 1985 and January 1986. The craft would then continue on toward Neptune, though deputy project manager John Casani said it would take "a miracle" for the spacecraft to continue in operational condition out to Neptune.

Two Mariners are scheduled for launchings in August and September 1977. Though launched one month apart, the first Mariner will swing beneath Saturn in November 1980, nine months ahead of the other craft. The second Mariner, directed toward the outer portion of the solar system on a lower speed trajectory than its predecessor, would receive a gravitational boost from the ringed giant that would send it on to Uranus.

The Uranus mission depends upon the success of the first Mariner. If it satisfies scientific requirements during its examination of Saturn and Titan, the gas giant's largest satellite, and if the second Mariner exhibits signs of a long and active life, the se-

Uranus *continued on page 47*

Pioneer Passes Saturn

Pioneer 10, history's first traveler out of our solar system, crossed the orbit of Saturn on Feb. 10.

Designed to investigate the Jovian planet and the asteroids between Mars and Jupiter, the vehicle is man's first serious attempt to communicate with extraterrestrial intelligence. The now-famous Sagan/Burgess/Sagan plaque — the "message" aboard Pioneer 10 — conveys information about the nature and location of the craft's fabricators that hopefully will be seen and understood by some galactic being.

Slightly damaged by radiation during its flyby of Jupiter in December 1973, Pioneer 10 provided the first close-up photographs of the giant planet, mapped the Jovian magnetic field (confirming the belief that Jupiter's north magnetic field is to the south), sought auroras in Jupiter's polar atmosphere and determined more precisely the masses of Jupiter and its four Galilean satellites. The spacecraft disclosed that Jupiter is a dominant source of high energy particles in the outer solar system (rather than the sun, as earlier postulated), and indicated Jupiter was much hotter at birth (4.5 billion years ago) than previously believed.

Many scientists and engineers had suspected Pioneer 10 would not succeed.

Pioneer 11, Pioneer 10's sister craft, is now making its first trip to Saturn carrying the same message. It will begin studies of the ringed planet sometime before its arrival in September 1979. Pioneer 11 came within 26,000 miles of Jupiter's cloud cover in December 1974 while studying the giant planet.

When Pioneer 10 crossed Saturn's orbit, it actually was 80 million miles above the ringed planet's orbit. During the "intersection" of craft and orbit, Pioneer 10 was 860 million miles from the sun and 892 million miles from Earth.

Pioneer 10 received a gravitational boost from Jupiter during its last orbit of the planet that increased its speed to over 100,000 miles an hour, a speed record later surpassed by Pioneer 11.

Once past Saturn, Pioneer 10 will cross Uranus' orbit in 1979 — two billion miles from Earth — and leave the solar system in 1987. Project officials hope radio communication with the craft will continue well beyond the seventh planet's orbit.

Pioneer 10 will pass the vicinity of Earth's closest star outside the solar system, Proxima Centauri, 80,000 years from now. The ship is headed toward a point near the boundary of the constellations Taurus and Orion. There are no nearby stars in this direction.

Exobiologist-astronomer Carl Sagan pointed out in his book, **The Cosmic Connection**, that during the spacecraft's 10 billion year lifetime, it would "not enter the planetary system of any star, even assuming that all the stars in the galaxy have such...systems." Though its nuclear power source will die in several decades, the vehicle, traveling at 25,500 m.p.h., should be preserved by the vacuum of space.

"It is conceivable," Sagan mused, "that the spacecraft will be encountered by an extraterrestrial civilization only if such a civilization has an extensive capability for interstellar flight and is able to intercept and recover such silent space derelicts."

Pioneer 10 has not been idly whizzing through space since overtaking Jupiter. It is returning data on the sun's atmosphere, the interstellar medium, cosmic rays from within and outside the solar system and the ratio of elements in space.

ASTRO-MART
only in ASTRONOMY

Jittery X-Ray Source Found in Sagittarius

A new subspecies of pulsing x-ray sources — one that generates x-rays in the same way a drunkard speaks — has been found. The source appears to be a globular cluster in the constellation Sagittarius.

Until now, all observed pulsing x-ray sources have exhibited regular signal bursts.

The jittery source, located by scientists at the Massachusetts Institute of Technology using data obtained by the Astronomical Netherlands Satellite, spews out bursts that rise to maximum in about 1/2 second and die down within 10 seconds. Bursts occur on an average of once every 4 hours 22 minutes, but the period is not precise. Pulses have been observed to differ in their periods by as much as 17 minutes.

Pulsed signals have been attributed to pulsating or rotating bodies, but the mechanism responsible for the variable bursts is unknown.

If the source is located in a globular cluster in Sagittarius, each pulse throws out 1,000,000 times the radiation expelled by the sun.

Identity Crisis Faces Planetary Scientists

Space scientists, overwhelmed by the flood of information recently compiled on planetary features, are grappling with an identity crisis.

Faced with optical and radio obtained close-ups of Mercury, Venus and Mars, scientists must now come up with names for these contours. Names of explorers and scientists have been applied to planetary configurations in the past, but the scientists, sensitive to cultural considerations, are seeking the advise of scholars in the humanities to get the widest possible representation from different cultures, past and present.

Working through the International Astronomical Union, astronomers and space scientists decided (during a meeting on the problem in Moscow last year) to assign the names of famous women in history and mythology to Venusian features mapped by Earth based radio stations. The monikers of painters, authors, composers, sculptors and architects will be carried by some 250 major features of Mercury recently detected by Mariner 10, according to Dr. Donald Morrison, chairman of an international panel on Mercurian names.

Features on Venus cannot be detected visually because of its dense, opaque cloud cover. Radar observations of increasing sensitivity scan the veiled planet every 21 months during the planet's closest approach to Earth. Observations of Mercury by telescopes on Earth are blocked by the planet's close proximity to the sun.

Mars would also have names from the humanities applied to newly discovered small features, although Soviet scientists have rejected such suggestions. The Soviets suggest a fresh start on a new planet, with large formations named after authors and people in all branches of the humanities. Many of the Martian craters, canyons, plains and mountains already bear the appellations of scientists and explorers.

NASA Cuts LST From Budget; Angry Astronomers Press Congress

Astronomers, reacting to news that funds for NASA's planned Large Space Telescope (LST) are being cut from the fiscal 1977 budget, are exerting pressure on Congress to find a way to continue program funding.

The budget cut has caused backlash among astronomers against NASA and the LST program. Claiming NASA has "disregarded the recommendations of its outside scientific advisory groups, as well as the overwhelming support of the scientific community," some scientists have suggested that NASA "used science to sell the shuttle and now has shoved science aside."

The Senate Aeronautical and Space Sciences Committee and the House Science and Technology Committee have reported receiving numerous letters from scientists expressing displeasure over the Office of Management and Budget's decision to cut funds for the LST from NASA's budget request.

Tentatively planned to be launched by space shuttle into orbit around Earth in 1983, the LST would contain a 95 inch (2.4 meter) Schmidt-Cassegrain telescope coupled to television cameras and spectrum analyzers. Enthusiastic supporters of the LST call it "the ultimate telescope".

Potential advantages over Earth bound instruments are many. Because the LST won't have to contend with Earth's atmosphere, there will be no blurring of phenomena; also, ultraviolet and infrared radiating objects normally invisible to observers on Earth would be disclosed by the LST. Objects as faint as 28th magnitude would be visible to the instrument, compared to the 23rd magnitude barely visible to Earth's largest land based telescopes at Hale Observatories.

The LST originally was scheduled to contain a 118 inch primary mirror, but NASA concerns over costs and future budgetary allowances pared down the telescope's aperture.

Uranus

continued from page 45

cond craft will be given the go-ahead for the Uranus encounter.

Adding Uranus to the itinerary would increase project costs by $21 million. The estimated cost of the project without the Uranus flyby is $305 million.

Trajectory modifications have already been computed and modulations in the second Mariner's infrared spectrometer (to enable it to take Uranus' temperature) are underway.

The craft will photograph Uranus and gather data on the planet's atmosphere and magnetic and gravitational fields.

Sun

continued from page 45

A third article in **Nature** by two Cambridge University theoreticians considered the implications of the Soviet and British findings. Unable to account for the underlying cause, the two scientists noted that the discovery presents the exciting prospect of studying the interior of the sun in the same fashion that seismologists study Earth's structure.

Theorists have proposed several exotic explanations for the observed oscillations. Dr. Donald Clayton and two colleagues of Rice University have suggested the sun's energy source is a black hole located at its center that gradually is swallowing solar matter. English cosmologist Sir Fred Hoyle has suggested that the sun was formed in two stages: The inner portion, formed first, was richer in metals than the outer layer. The core, Hoyle theorizes, is so dense that radiation cannot escape and must be removed by rising currents.

Another theory, suggested by Dr. William Fowler of Caltech, postulates that nuclear reactions in the solar core are burning down, leading possibly to a future ice age on Earth.

Soviet astronomers at Crimea Observatory have suggested that the accepted source of solar energy — nuclear fusion of hydrogen atoms to form helium nuclei and release energy — is incorrect. The actual reaction, they say, is presently unknown to science.

The source of the dilemma is the failure of detection of the predicted number of neutrinos by the giant neutrino "telescope" established by Dr. Raymond Davis and buried a mile beneath the Black Hills in South Dakota. Davis' experiment (using a 100,000 gallon tank of cleaning fluid in which neutrinos react with chlorine atoms to form radioactive isotopes of argon) is the only one that promised any information on the sun's interior. His finding that there are about five times too few neutrinos detected to fit current solar models is a cause of major concern among astronomers.

Von Braun Initiates Space Organization To Promote Benefits

Wernher von Braun, former NASA administrator and space scientist, plans to launch a new space organization, the National Space Institute (NSI).

The purpose of the NSI, Von Braun said, is twofold. It will rekindle public interest in space and will address itself directly to private industry, focusing attention on benefits obtained from space related research and development.

The organization is presently establishing a national program that identifies products generated or improved by space research.

The German-born scientist believes that curiosity in space matters has sagged just at the point when dividends from programs of the 1960s should be pouring in. He related the situation to the farmer who carefully planted and tended his crop and then claimed, when harvest time approached, he could not afford to hire pickers.

Funded entirely by contributions from individuals and corporations, the NSI is headquartered in Arlington, Va.

BRIEFS

- A hot subdwarf companion of the yellow giant *a* Puppis has been discovered at far ultraviolet wavelengths photographed by Skylab in 1973. Invisible from Earth, the companion is believed to be in the process of contracting into a white dwarf. The faint, blue star, much hotter than its 10,000 degree Fahrenheit neighbor, is suspected to be more massive than the sun.

- Those violently active galactic misfits, Seyfert galaxies, are believed to be blustering counterparts of quasars, differing only in degree of activity. Recent Lick Observatory observations of iron emission of 13 Seyferts strengthened the suspected bond. One Seyfert, Markarian 376, displayed strong, broad, nonthermal iron emission previously detected in two quasars. How the emission is generated, however, is not yet known.

- A Florida sociologist is teaching a noncredit course in extraterrestrial relations. The first thing he instructs his students to do when meeting an alien? Don't panic.

PUBLISHER'S MEMO

Egad! This month's Publisher's Memo is not what I promised last month. Due to the length of our lead features and Photography in Astronomy this month, the introduction of ASTRONOMY employees (with photos) will have to be delayed till the May issue. Hope you don't mind.

Anyway, I've got a couple of things to tell you about first that don't require three pages. The July 1976 issue of ASTRONOMY will be our special American Bicentennial offering. This issue will be larger than normal (96 pages) and will be devoted entirely to the history of astronomy in the United States. Not only will that issue document American astronomy's history during the past 200 years, but it will include important events and discoveries during the 150 year period prior to the signing of the Declaration of Independence. In addition, Star Dome in that issue will be completely devoted to the astronomy practiced by, and sky lore mythology of the American Indian.

We believe the July 1976 issue will be very special — something that, in a very short time, will become a highly valuable and important collector's item. Because of this and the greater costs involved in preparing this special issue, it will bear a special cover price of $3.50 per copy.

However, current subscribers, or anyone who subscribes to ASTRONOMY before July 1976, will receive one copy of this special issue as a part of their normal subscription. In other words, subscribers will receive the July 1976 issue plus 11 additional issues for the regular $12.00 per year subscription price.

Anyone ordering that one issue alone — including subscribers who order *additional* copies, will be charged $3.50 per copy.

Important, time valued information such as the Planet Finder, Sky Almanac and the Star Dome sky map will be published as usual in the July issue. However, Gazer's Gazette, Photography in Astronomy, Equipment Atlas, Stellar Frontiers, AstroNews, Astronomy Review, In Focus, Close-up and Eyepiece Impressions will be excluded to devote all available space to the history of U. S. astronomy. To make up for this, technical departments will be fattened somewhat in the May and June issues.

On another front, we'd like to share a little joke with you. Due to an oversight, the department stop banner topping the title page of the February Sky Almanac was flipped around and printed as a mirrored image. The symbol for the planet Mars normally appears at the left followed (to the right) by the symbols for Jupiter, Mercury, Venus, Saturn and Earth. In that issue, however, the mirrored reversal placed Earth first at the left, ending with Mars on the right. Mars' arrow, normally pointing right, pointed left; both Jupiter's "4" shape and Saturn's "h" shape were reversed.

Apparently nobody noticed.

Well, as it turns out, this little joke on both of us leads us to suspect that maybe it's time to examine each of our department stop banners and possibly redesign them. What do you think?

If you have opinions for or against, drop me a line to let me know. After all, your wish is our command. We await your direction!

Till next month, peace.

Sincerely,

Stephen A. Walther

Stephen A. Walther
Publisher

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The Astronomer's Starter Package - 6 by S & S Optika represents the ideal "first scope" for the serious beginning astronomer. Consider, for example, the mounting:

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S. M., Brooklyn, N.Y.

"Image of 3" almost identical to 11½-inch refractor"

"I feel obligated to write you about some of the results I am obtaining with my UNITRON 3" Photo-Equatorial. I have observed Uranus at its conjunction with Jupiter, and also Mars and Saturn with great satisfaction. I am equally pleased with my views of the Sagittarius clusters, the Andromeda Nebula, and the Moon. To my astonishment I have seen at 171X a view of Venus that was almost identical to those I have had through an 11½-inch refractor on open nights at the observatory. One feature I should like to mention is the relative light weight of the instrument, which is a boon for people like me who have to carry the instrument to to observing site."

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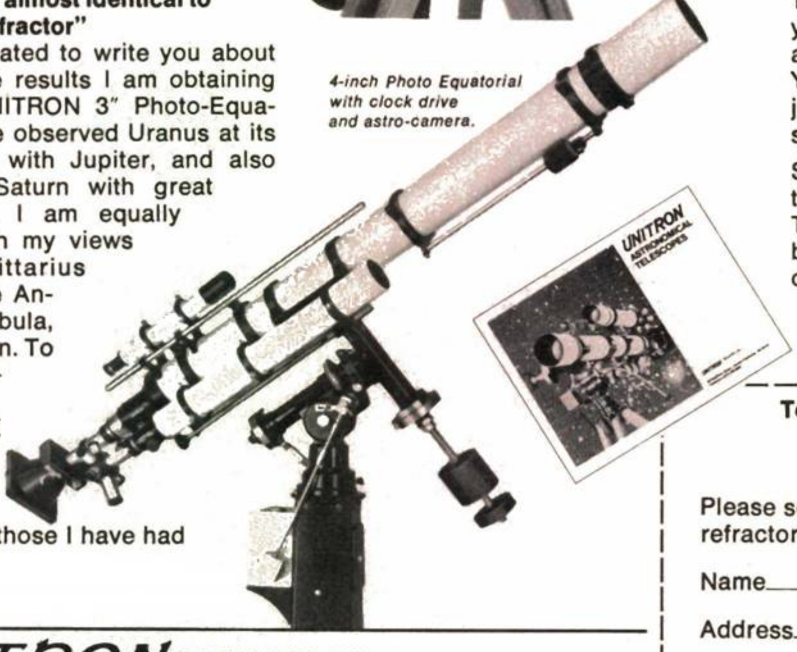

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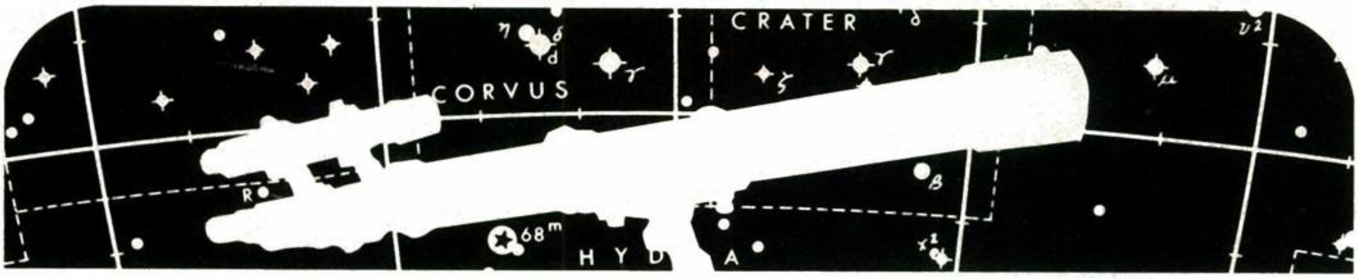


Your Most Valuable Equipment

by

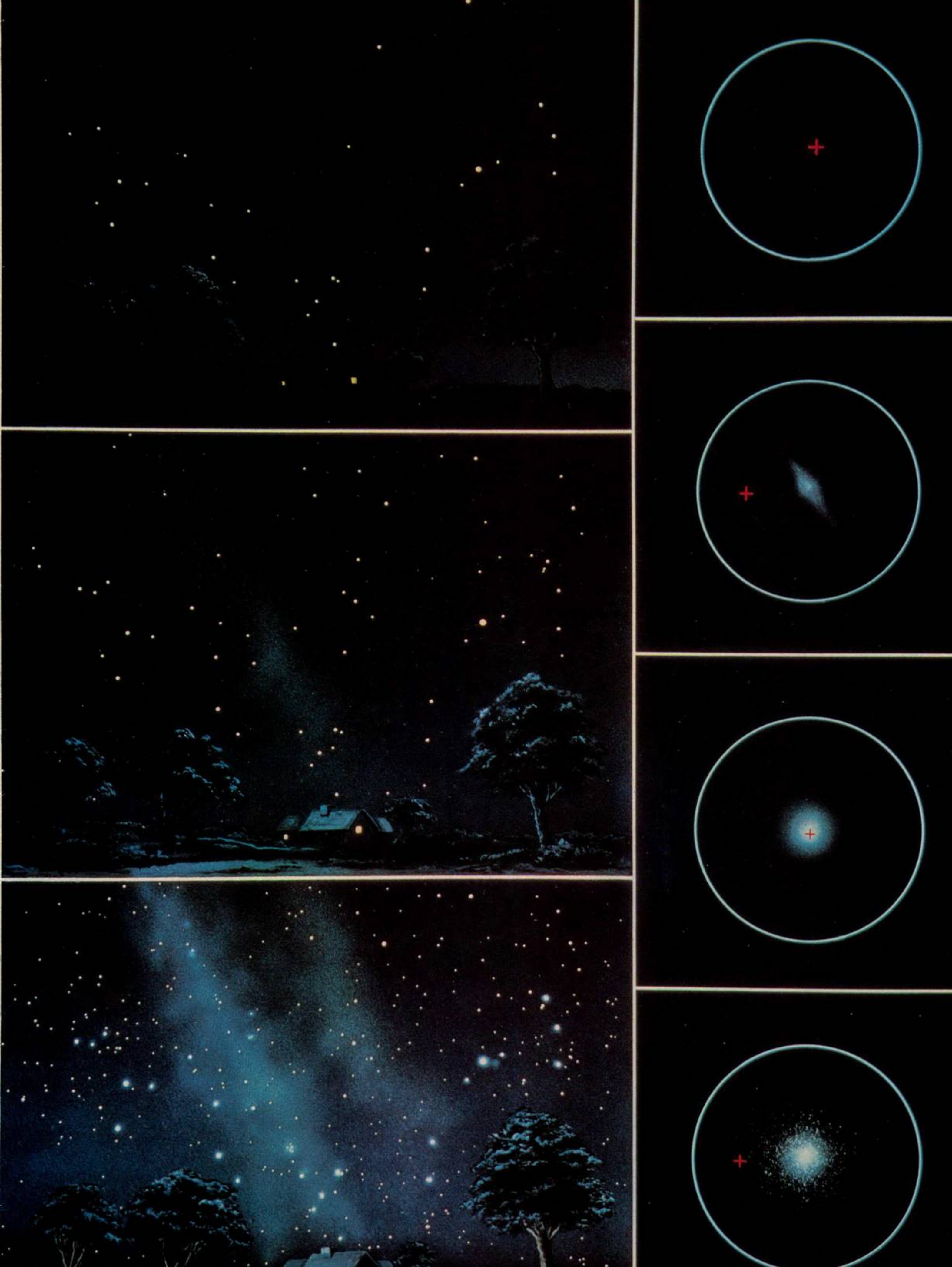
Richard Berry

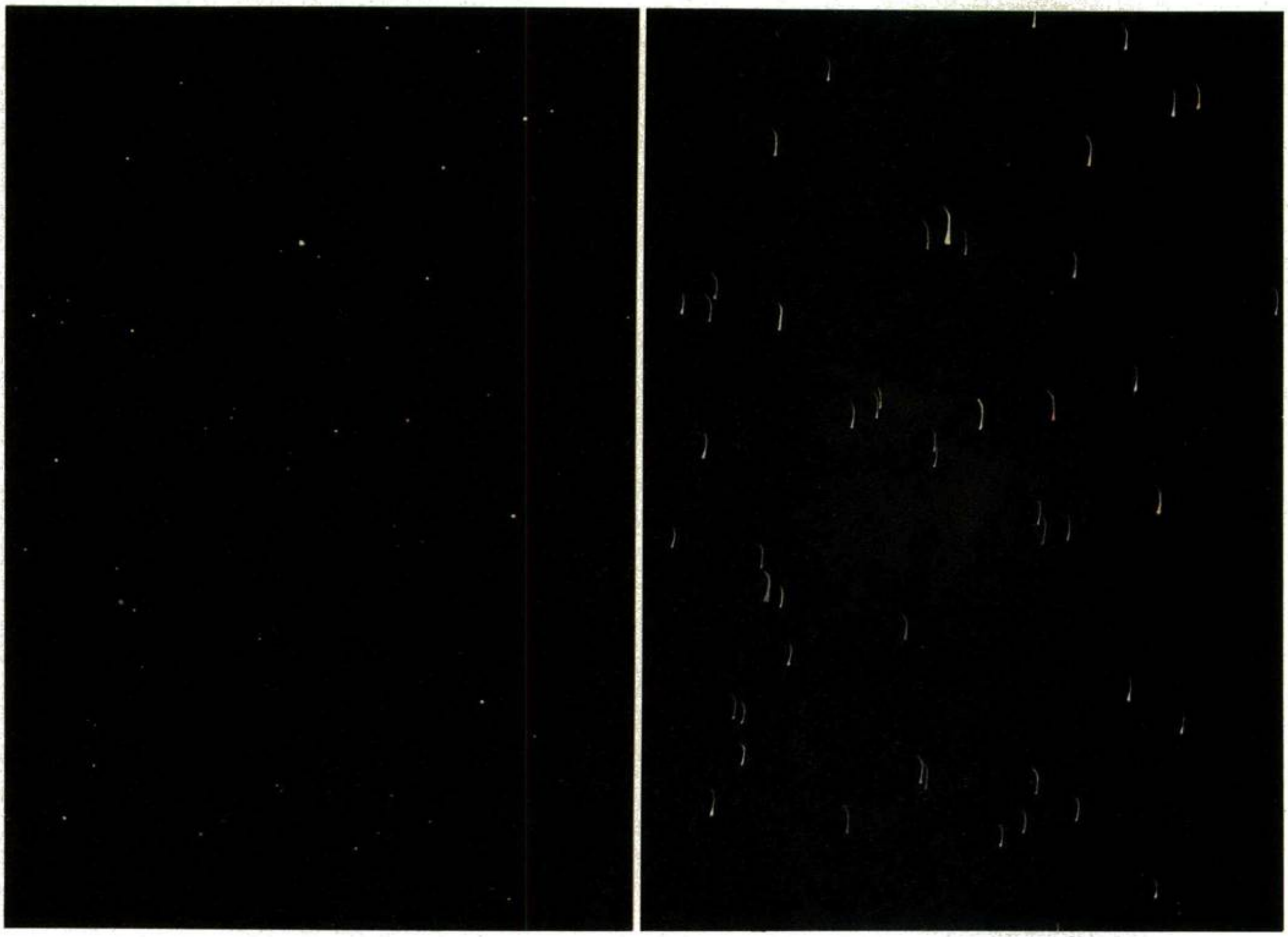
Your eyes are by far your most important astronomical equipment. But getting the best performance from them is not a simple matter; eyes must be used with the same care as all top quality telescopic and photographic instruments. Your eyes function over an enormous brightness range (nearly a billion to one)–from a glaring day at the beach to the dimmest galaxy barely visible in your telescope – and are automatically self-adjusting over the entire range. However, such versatility has a price: The time needed for eyes to adjust from bright light to the dimmest light is nearly an hour.

From normal roomlight levels, your eyes' sensitivity must increase a million times before you can detect faint nebulae in a dark sky. When you step outdoors, your pupils immediately expand, letting about 10 times more light into your eyes. After this, the retinas begin to adapt, becoming 100 times more sensitive during the first five minutes of adaptation. The pupils and retinas together account for a total eye sensitivity increase of 1,000 times during the first five minutes of adaptation. Then, after resting for a few minutes, your eyes renew their plunge into sensitivity; within 30 minutes, another 100 fold adaptation has occurred. It takes about an hour for most people's sensitivity to increase a million times.

Once fully dark adapted, your eyes are among the most sensitive light detectors known. Most city and suburban astronomy enthusiasts, however, never reach full dark adaptation while observing, because sky and streetlights are always so bright that their eyes can't reach maximum sensitivity. If you choose your observing site carefully (to minimize the effects of streetlamps), or work inside a shelter or obervatory where lights don't shine in, you can see more through your telescope. To help dark adaptation, observe with a piece of black cloth (about a yard square) thrown over your head and the eyepiece. You'll look funny, but under the cloth the only light you can see comes from the view through the eyepiece – so your dark adaptation will be much better.

Two properties of the eye are pictured in the drawings on the opposite page. The diagrams at left illustrate the effects of dark adaptation. The top drawing shows a section of the sky (the southern Milky Way) as seen directly after the observer steps outside; the basic constellations, and little else, are visible. After 10 minutes, the Milky Way begins to appear, and when the eye is fully dark adapted in about an hour, the sky appears as shown at bottom. The circled drawings at right demonstrate the technique of averted vision. Instead of looking squarely at a galaxy or globular cluster, look to one side of the object as indicated by the red crosses. More detail in the galaxy is visible, and the cluster can be resolved into stars even near the center. Averted vision allows starlight to focus on the more sensitive parts of the retina, making added detail visible. Artwork by Victor Costanzo.





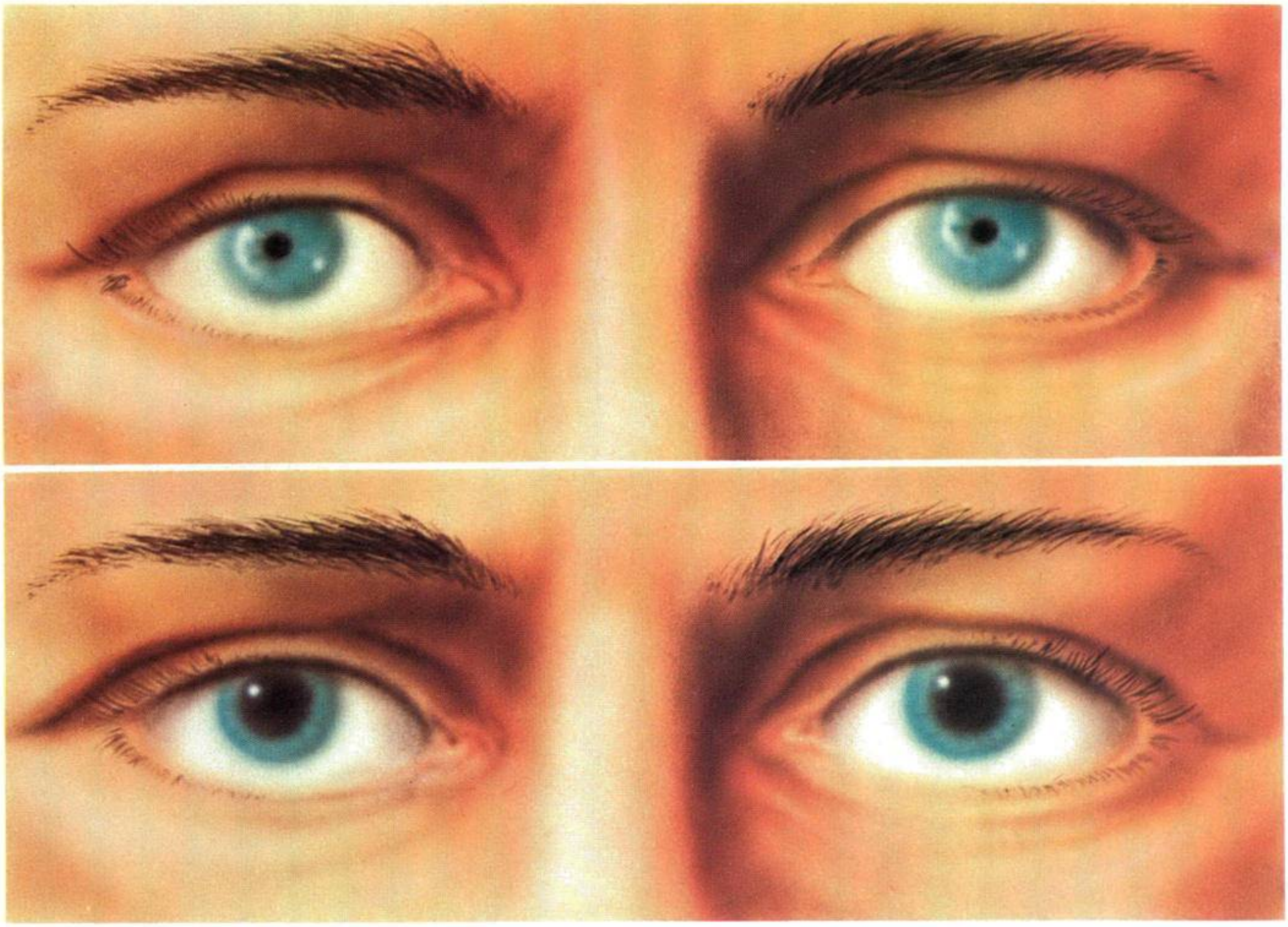
The diagram at left shows an apparently empty star field as seen through the telescope. When the instrument is jiggled very slightly back and forth, however, faint nebulosity springs into view (invisible when the telescope is held still). This trick works in a manner similar to averted vision: The nebula "pops out" because the eye is not straining to see it directly. Artwork by Victor Costanzo.

Fatigue and exposure to strong sunlight can limit your eyes' adaptation ability. Naturally, it's usually hard to avoid fatigue at 3 a.m., but knowing that you can see more when you aren't tired might help you get a little rest before you start observing. Similarly, after a day at the beach, your night vision will be poor, so rest your eyes for a few hours to restore sensitivity.

Red light is less damaging to dark adaptation than any other color, so all lights you use ought to be red. To read maps or charts, a dim light is a must. You can dim a flashlight by taping one or two sheets of red paper over the front, or by using a red cellophane filter and a sheet of white paper to diffuse the light. Red goggles really help – you can make your own by purchasing an inexpensive pair of sunglasses, removing their gray lenses, and replacing them with red acetate plastic or cellophane. Wear the goggles whenever you aren't actually looking through the telescope to maintain your adaptation.

Once dark adapted, you'll notice that faint objects often are more easily seen when you don't look directly at them. Sometimes it seems that as soon as you look, the object disappears. This effect is caused by peripheral vision which is more light sensitive than central vision (although not as sharp). Take advantage of this property to see fainter objects simply by looking beside what you want to see – a technique called *averted vision.* Before it works right you'll need practice, but once you've learned how, you'll be able to detect objects you couldn't see otherwise. Jiggling your telescope a very little bit is another trick that helps you see dim objects.

Any one of several eye conditions can affect your astronomical observation. In myopia (nearsightedness), your eye is unable to focus on distant objects, and stars look like large blobs of light instead of pinpoints. Hyperopia (farsightedness) does not affect astronomical viewing, but it makes chart and map reading difficult. Glasses or contact lenses correct both these conditions, but in either case, you can focus the telescope perfectly for your eye both with and without glasses. Astigmatism makes observing a lot harder: Stars look like streaks or lines of light. Glasses can, again, correct this condition for normal viewing, but for low power viewing with a telescope, you'll need to keep your glasses on. You can focus well without them for high power viewing. If stars look to you like perfect, sharp little points



In order to detect faint objects in the night sky, the eyes must become dark adapted. The pupils are contracted (top) in normal roomlight levels; as soon as the observer steps outside under a dark sky, the pupils begin to expand, letting more light into the eye. When fully dark adapted (bottom), the eye's sensitivity has increased one million times. Artwork by Victor Costanzo.

of light, you're one of those lucky people with perfect vision.

As you grow older, your eyes slowly lose their ability to change focus. This condition (called presbyopia) can be corrected with bifocal or trifocal glasses; but you'll always be able to focus the telescope for your eyes' particular needs. Also, your eyes' pupils get stiffer with age. When you're young, the pupil may open up to 7 or 8mm, but by the time you reach your forties it may not open more than 5mm. You'll have to take care to use an eyepiece that gives an exit pupil smaller than your eyes' pupils when you're using richest field telescopes or binoculars. Since the size of the exit pupil is the aperture of the telescope divided by the power of the eyepiece, you can match the power to fit your age.

Your ability to see color disappears in faint light, which is why you can't visually see the nebular colors that you see in photographs. Because your eye has two types of light receptor cells — color-sensitive cone cells, and rod cells, which are sensitive to very faint light but not to color — when you dark adapt, you "shift" from the cones to the rods. The complex interactions between the cells are different at various light levels due to the different cells and nerve fibers involved. So when you see an object (such as the dull red, eclipsed moon) in the sky and then look at it through your telescope — a magnified but dimmer view—you'll see the color and contrasts of the moon in a different way, because your eyes use different types of sensing cells. You'll have to experiment to find what power gives you the best view when you examine faint galaxies. The power of eyepiece used changes both the brightness and size of the galaxy. In bright suburban skies, high power will usually work best, while in dark country skies, a lower power gives the best view.

The sun is at the other end of the brightness scale. Sunlight concentrated and focused by a telescope *can blind you in a fraction of a second.* To be safe, you *must* project the image of the sun onto a screen (see "Build a Projection Screen", ASTRONOMY, September 1975), or use a safe reflection type filter securely mounted over the objective of the telescope.

So there you are—your eyes, like all your other equipment, require some skill and knowledge to use to the fullest. At the same time, however, they are wonderfully versatile and easily adaptable, both to the wonders of astronomy and the daily job of seeing.

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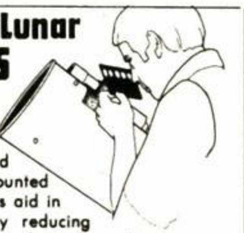

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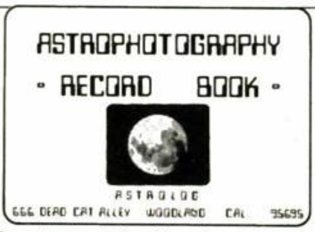

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GAZER'S GAZETTE

Mars Occults Star

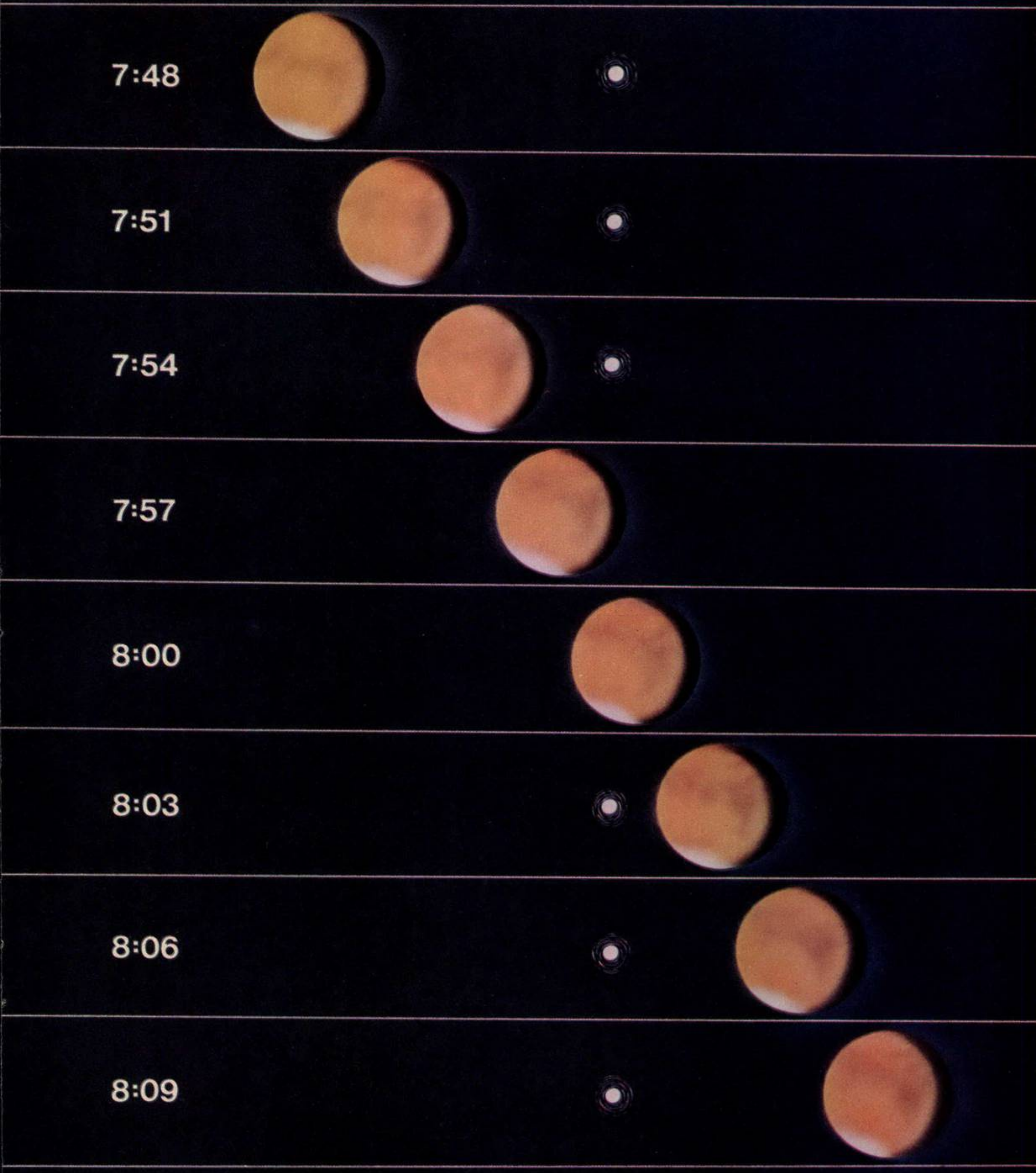
One of the most exciting things about astronomy is its combination of the precise and the unexpected. The April 7 occultation by Mars of the third magnitude star Epsilon Geminorum will serve to emphasize this statement. Scientists can calculate the exact time and duration of this tiny eclipse, as well as the parts of Earth from which it will be visible. Yet there's no way to predict the occultation's actual appearance — and this is where the unexpected enters the picture. No matter how many descriptions the observer may read before the event, there's no substitute for the real thing, and every different observation will be unique.

Additional excitement can be derived from the extreme rarity of the occasion; there's something particularly enjoyable about being "in" on such an uncommon event. Planetary occultations are so infrequent that most observers' guides don't even mention them. The last important one happened in 1971 when Jupiter occulted Beta Scorpii (unless you want to include the brief eclipse of Kappa Geminorum by the asteroid Eros that occurred in January 1975).

Such occultations are natural consequences of the planets' orbital motions. We know that the entire sky has an apparent east-to-west motion caused by Earth's rotation. Mars (as well as the other planets) hurtles along its orbit, but it also travels in the opposite direction against the background of the stars. This motion cannot be detected with the naked eye except over fairly long periods of time — two weeks or more. And even through a telescope, Mars shifts its position only slowly from night to night. But occasionally, from our viewpoint, Mars will catch up with and pass in front of a star. At such times, Mars' orbital motion becomes readily apparent because the star reappears on the opposite side of the planet's disk a few minutes later.

The same thing happens with the moon: As it revolves around Earth, the moon can move in front of stars and block their light. But the moon covers a much larger area of sky than a planet like Mars

The diagram on the opposite page shows successive stages in the April 7 occultation by Mars of Epsilon Geminorum. Mars will be in a slightly gibbous phase, and the star will disappear a few seconds before the visible portion of the planet's disk reaches Epsilon's position. The diagram presents the occultation as it will appear telescopically, with south at top. Times given are Eastern Standard; farther west, the event will take place during twilight, or while the sun is still in the sky. Artwork by Victor Costanzo.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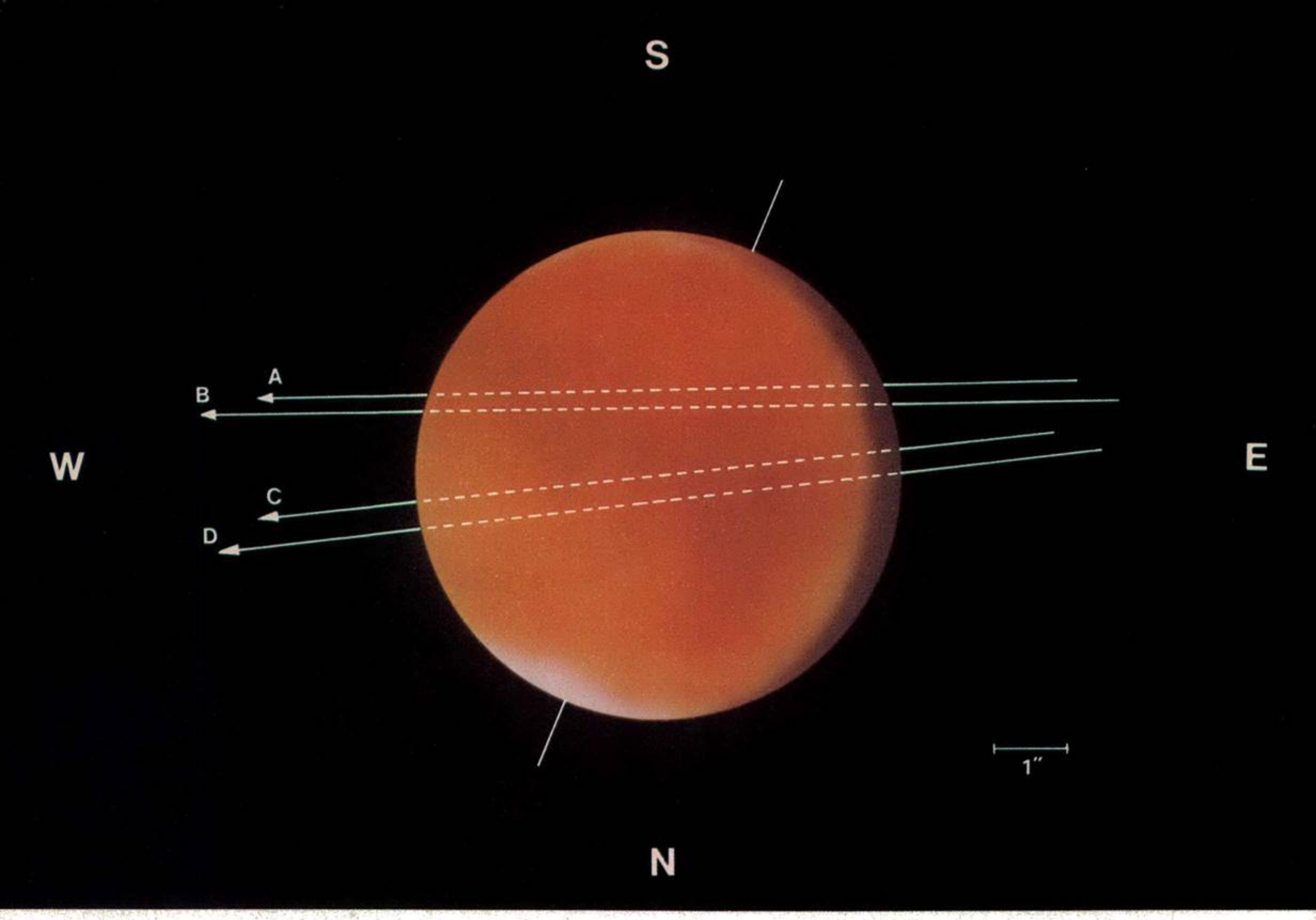


does, and thus there is more opportunity for the moon to hide stars. Lunar occultations are rare enough that we never become jaded to them, but they can seem almost like everyday occurrences in comparison with planetary occultations.

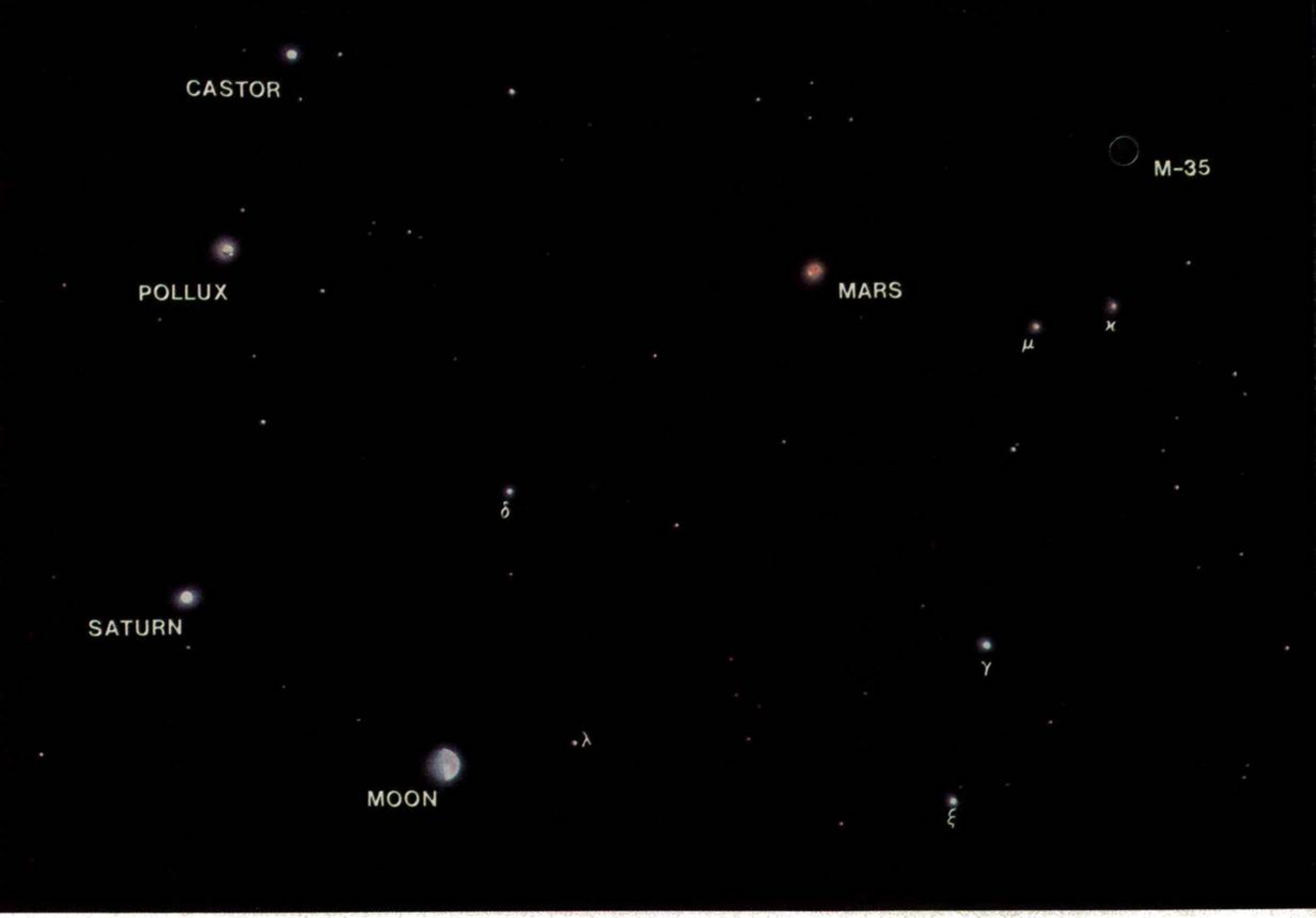
This spring's occultation will be visible over most of eastern North America, and Mars will completely cover Epsilon anywhere between Hudson Bay and the Panama Canal. Unfortunately, though, not all observers in the United States will be able to watch the event; it occurs before sunset west of longitude 100 degrees. If you live in the central time zone, Mars will occult Epsilon during twilight, and you may need to be sharp-eyed if you're using low power optical aid. East coast observers will have the best view, for there the occultation will take place against a dark sky.

Twilight observers may need help in finding Mars against the fairly bright sky. The first quarter moon and Saturn provide convenient reference points; Saturn is situated between the moon and Mars on April 7, and a line drawn from the moon to Saturn and extended an equal distance beyond will locate Mars. The planet's distinctive red color will help.

The occultation will begin at 7:57 p.m. EST and 6:56 p.m. CST, at which times Mars will be quite high in the western sky. It will last different amounts of time, depending on the observer's latitude. For those who live about 38 degrees north, the occultation will be central — that is, Epsilon will reappear exactly opposite the point on the disk at which it disappeared — and will last just under 4-3/4 minutes. Farther north, Epsilon will pass behind the northern part of Mars' disk and will not be hidden as long. The same holds true for observers farther south.

During its April 7 occultation by Mars, Epsilon Geminorum's apparent path behind the planet's disk will vary depending on an observer's position on Earth. Texans will see the star's obscured path at A; astronomers at Palomar Observatory in southwestern California will find it at B; District of Columbia viewers will detect its motion at C, and Toronto observers will see it at D. The diagram on page 63 shows the star field as it will appear immediately before the occultation. Artwork by Victor Costanzo.

If you plan to watch the occultation with the naked eye, it won't be nearly as dramatic as with a telescope. In fact, by the time the sky darkens enough for Mars to be plainly visible, it will already have drawn so close to Epsilon that you won't be able to distinguish the two — like trying to split a double star without a telescope. For about an hour before and after the occultation, Mars and Epsilon will be too close together to resolve, which might make Mars slightly brighter than normal (its magnitude on April 7 will be +1.2, almost two magnitudes brighter than the star).



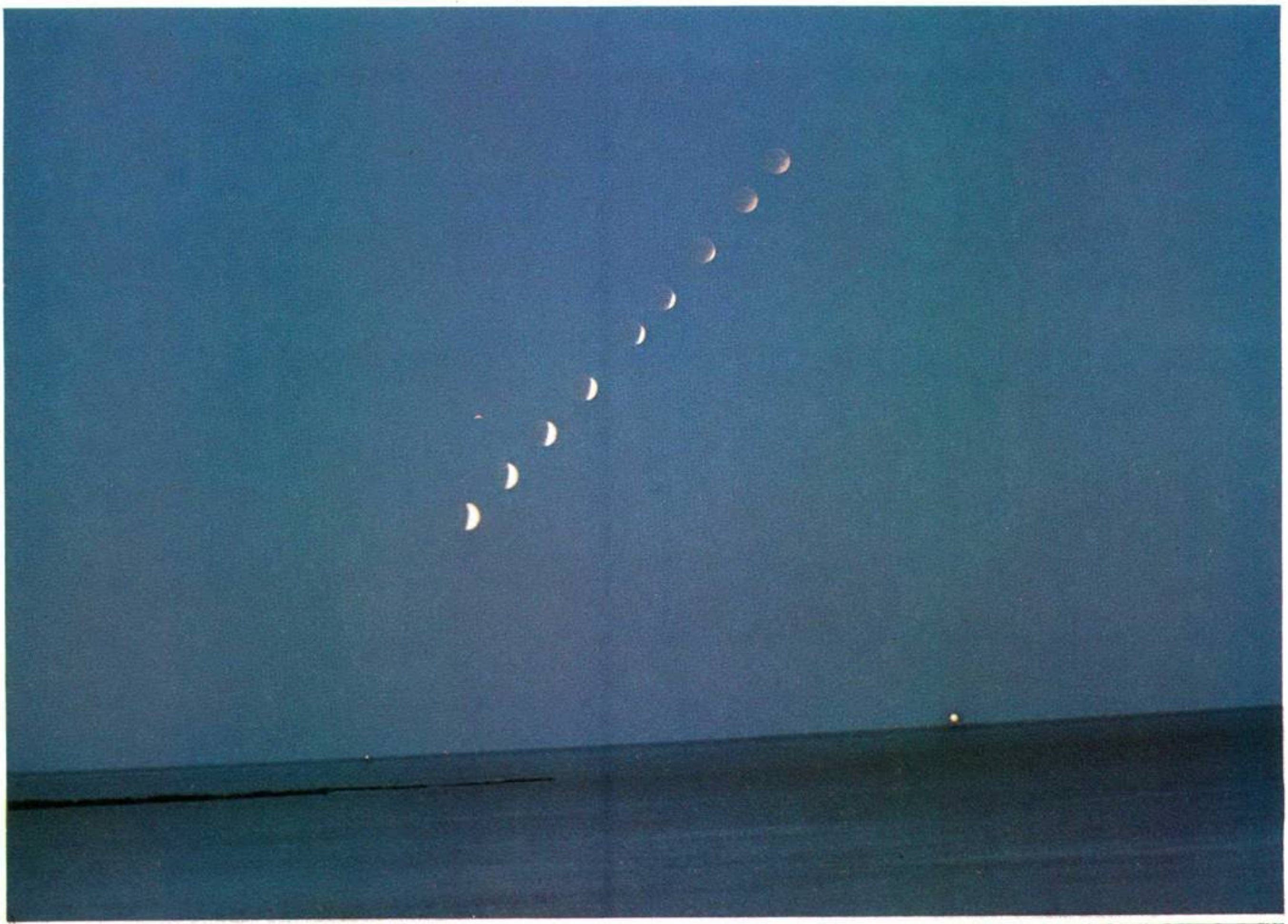
Adding a little optical aid will help a lot. Six or seven power binoculars will resolve Mars and Epsilon much closer to the moment of occultation. You'll be able to separate them until about five minutes before the occultation. After that, you won't be able to see much more than the red-orange pinpoint of Mars. Large binoculars, such as 20 x 80s which will just barely show the disk of Mars to a sharp-eyed observer, will also allow you to just see Epsilon fade out as Mars passes over it.

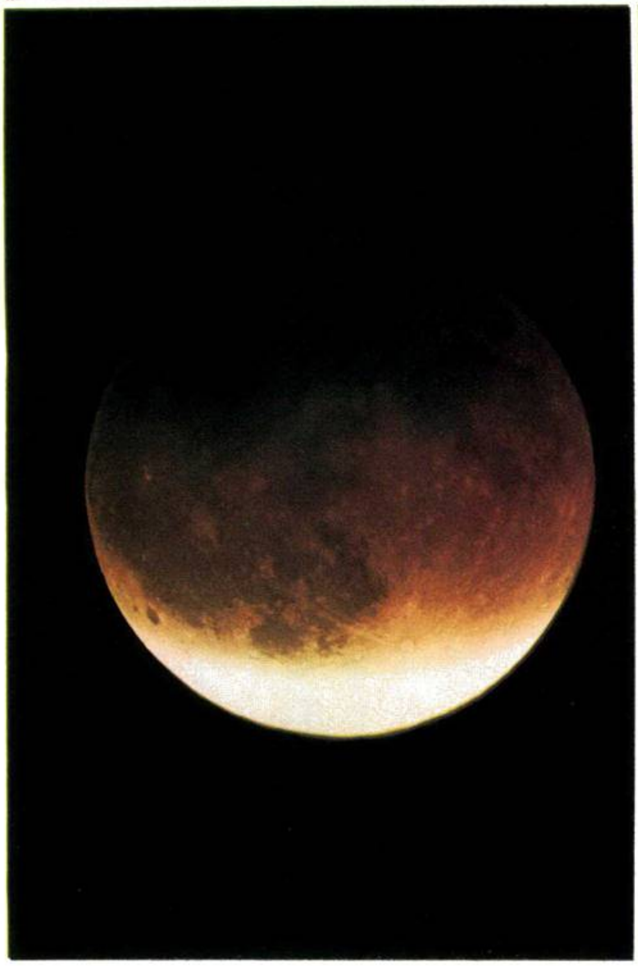
A small telescope such as a 2.4 inch refractor will show Mars only as a small, fuzzy disk, even at 120 power. Mars' angular diameter on April 7 is not large — only 6.37 seconds of arc. But in such a telescope, Epsilon will remain clearly distinct as Mars approaches it. Just before occultation, the two images may seem to merge for a minute or so, and then Epsilon will suddenly fade from sight. A bit less than five minutes later, Epsilon will fade back into sight and Mars will slowly pull away.

With bigger scopes (six inches or larger), Epsilon will glow more brightly than Mars' surface if the seeing is good, creating a dazzling spectacle as Mars nears it. Why is this so, if Mars is brighter than the star? In a large telescope, the light from Mars is spread out over a rather large space while all of the star's light is concentrated into a single point, and Epsilon is much brighter than a similar sized section of Mars' disk. Despite this, Mars' ruddy glow will contrast with the yellow-white sparkle of Epsilon as it approaches the star at 1.4 seconds of arc each minute. If you've got a six inch telescope with a resolving power of 0.8 seconds, you might expect Epsilon to be lost, or unresolved about 30 seconds before the actual occultation. But it won't be lost from sight because of its brightness, and until Mars actually moves in front of Epsilon, you'll be able to see it.

When Mars does cut off the star, some interesting things may happen. We don't really know how Mars' upper atmosphere will bend the starlight in those last few moments. The star may simply fade out slowly in about a second, or it may be cut off quite abruptly. The light may be irregularly bent, causing several flashes or flickers to be seen from Earth. When Jupiter occulted Beta Scorpii in 1971, observers on Earth could see flashes as the star's light traversed different layers of atmosphere. But Mars has a much different atmosphere than Jupiter does, and we can't really make any predictions on that basis.

So it's an open question, and the best way to find out about the occultation is simply to see it. If you have a large telescope, be on the lookout — you probably won't get another chance at something like this for a long time!





SKY ALMANAC

Mercury Brightens Meager Sky

After last month's planetary abundance, the April sky presents a bit of a comedown. The two brightest members of the solar system (Venus and Jupiter) are too close to the sun for observation, while the other bright planets are headed away from Earth and fading as they go. But the appearance of Mercury and a rare occultation should provide some excitement and make up for the diminishing returns gained from planetary observation.

Mercury

If you were able to glimpse all seven planets that were in the sky during March, you can complete the list this month when Mercury becomes visible. The smallest planet will be a first magnitude object low in the west after sunset in the latter part of April, and reaches greatest eastern elongation on the 27th.

Mercury is probably the most difficult planet to observe (with the exception of Pluto) because of its nearness to the sun—its average distance is 36 million miles. It speeds along its orbit like the winged messenger from whom it takes its name, requiring only 88 days for one complete trip.

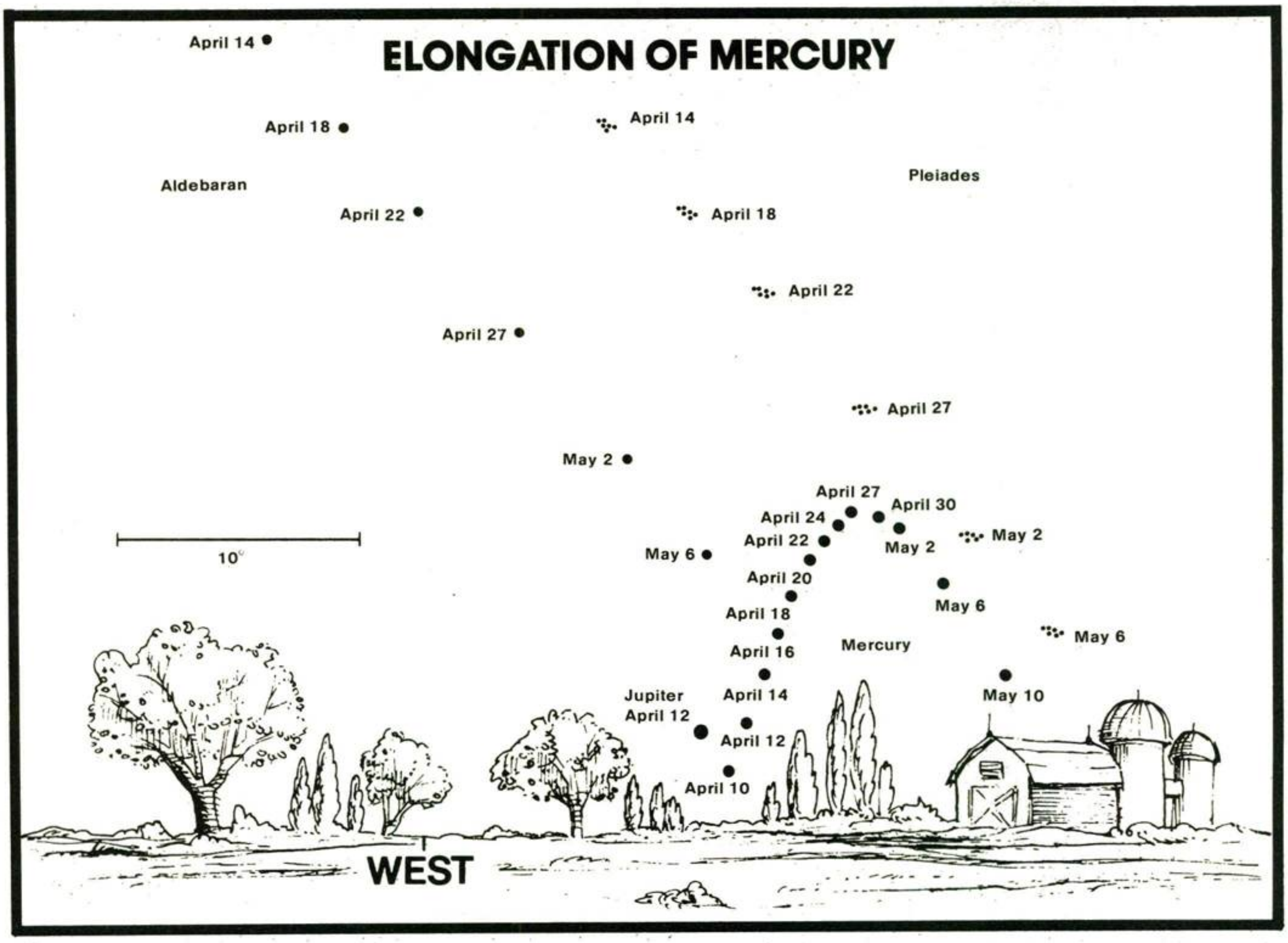
Because Mercury is nearer the sun than is Earth, it does not reach opposition like the outer planets, and is never visible all night. Instead, it appears to swing from one side of the sun to the other, and it's best seen when at either end of these swings. At such times, we say Mercury has reached *greatest elongation*—that is, the angular separation between Mercury and the sun is at its widest. At greatest eastern elongation, the planet is visible after sunset, and before dawn at greatest western elongation. To avoid possible confusion, note that when Mercury is at greatest eastern elongation, you see it in the western sky, and vice versa. Venus goes through the same routine, except that Venus — being farther from the sun—spends more time on each of its orbital swings and is easily seen for several months consecutively. At the best of times, you'll see Mercury for only about 30 days.

As the moon rose over the Atlantic Ocean on the afternoon of Nov. 18, 1975, it crawled into the umbra of Earth's shadow and became totally eclipsed. The multiple exposure shot on the opposite page was taken from Schoodie Point, Maine. High Speed Ektachrome film, exposed for one second at five minute intervals through a 70 mm f/5.6 lens, shows the moon slowly darkening as it rises. The light on the horizon is from an off-lying island. The two pictures at bottom are selections from an eclipse sequence and are part of the photographer's first attempt at guided lunar photography. The shot at left is an eight second exposure on High Speed Ektachrome taken just after totality ended; a little more than an hour later, Kodachrome 64 was used for the 1/125 second exposure at right. Both photographs were taken through a Dynamax 8 at f/10. Top: Photograph by William Townsend; Bottom: Photographs by Joseph A. Stasio.

Fortunately, this month provides one of those best of times. During the spring, the ecliptic (the path along which sun and planets travel) is almost perpendicular to the horizon in the evenings, and Mercury's altitude above the horizon is correspondingly greater than in other seasons.

Look for Mercury in the west about a half hour after sunset, when you can just make out the planet through the twilight glow. You'll probably have your first sight of it this month around the 10th, when its magnitude is -1.4; it will be about two degrees above the horizon 30 minutes after sunset. A clear view to the west is a must for observing Mercury; even at greatest elongation it never gets any higher than 13 degrees or so above the horizon.

On the 12th Mercury will be about two degrees north of Jupiter. Since the two planets will be nearly the same magnitude, if you can find one, you'll find the other. Mercury's brightness drops as it nears elongation, but its increasing altitude compensates



The planet Mercury will be in its most favorable position for observing in 1976 when it reaches greatest eastern elongation on April 27. On that date, it will be visible above the western horizon for about an hour after sunset. The diagram above gives relative positions for Mercury and some of the brighter objects nearby during the month. After the 27th, Mercury will drop down in the sky and be lost to view by mid-May. Diagram by Victor Costanzo.

for the dimming. By the 26th, the planet's magnitude is +0.3 — more than a full magnitude fainter than it was on the 12th, but still bright enough to be a first magnitude object. On its elongation date, Mercury will be only a few degrees from the Pleiades (see the diagram on this page). During the first days of May, Mercury will continue to fade; after about May 10, it will be too dim to be seen through the twilight.

Mercury goes through phases much as Venus does, and a 2.4 inch telescope should be sufficient to show them. You can watch Mercury dwindle from nearly full to a thin crescent as it makes its orbital swing. On the 12th, 89 percent of its disk is illuminated, and Mercury, 5.5 seconds of arc in diameter. looks like a tiny gibbous moon through the telescope. As the planet reaches and passes elongation, its diameter grows to 7.6 seconds of arc on the 27th when its disk is 41 percent illuminated, and to 10 seconds of arc and only 15 percent by May 7. Obervation of the phases will be complicated by atmospheric turbulence near the horizon through which Mercury must be viewed.

Venus

Although Venus is still as bright as it was last month — magnitude -3.4 — its increasing nearness to the sun makes it more and more difficult to see. It rises only about 30 minutes before the sun, and unless you have a clear horizon you may miss it entirely.

Mars

Mars continues to fall behind Earth in the planets' race around the sun. Located in the constellation Gemini, its magnitude is +1.5 by the end of the month, when it will be about 157 million miles away. Mars' diameter decreases from 6.6 to 5.5 seconds of arc during April; the planet's disk is thus far too small for any worthwhile study of surface detail. However, Mars does present observers with a good show on April 7, when it occults the third magnitude star Epsilon Geminorum. For details on this extremely rare event, see this month's Gazer's Gazette and Photography in Astronomy.

Jupiter

Jupiter reaches conjunction on April 27, and throughout the month it is too close to the sun to be easily visible.

Saturn

The ringed planet is high overhead at sunset in the constellation Cancer, and it can be seen with ease during the early part of the night for the entire month. At magnitude +0.4, Saturn is dimmer than it was at January's opposition, and will grow successively dimmer during the next few weeks as it heads for conjunction with the sun. Saturn's distance increases from 816 to 860 million miles by April 30; correspondingly its disk shrinks from 17 seconds of arc to 16 , making this the last month for useful telescopic observation.

Uranus, Neptune, Pluto

The three telescopic planets are in good positions for observation. Details for observing Uranus and Pluto can be found in last month's Sky Almanac. Uranus reaches opposition on the 25th of this month. Neptune, located in Ophiuchus, rises about midnight and is visible during the latter part of the night. Pluto is just past opposition in Virgo.

Lyrid Meteors

For some reason, prominent meteor showers aren't as frequent in the spring as they are during other seasons. About the only ones that usually put on a good show are the Lyrids, which reach their maximum this year on April 22. The Lyrids, however, are only a moderate shower at best. Meteor enthusiasts aren't likely to derive much satisfaction from them—particularly this year, because the third quarter moon will rise at the same time as the Lyrids' radiant point (a little southwest of Lyra's brightest star, Vega), and moonlight will serve to obliterate all but the very brightest meteors. The radiant reaches the zenith at about dawn—as does the moon—and meteor shower fans would probably be well advised to wait for better things later in 1976.

Daylight Saving Time

All sky observers should note that Daylight Saving Time begins on Sunday, April 25. You'll have to adjust your observing schedules accordingly, for stars that were at the zenith at 9 p.m. during Standard Time won't reach that point until 10 p.m. under Daylight Saving Time. Most of the times given in ASTRONOMY from May through October will be Eastern Daylight Time.

Some readers may wonder why ASTRONOMY uses Eastern Time (Standard or Daylight) instead of the Universal Time found in many reference books. There are several reasons. Universal Time is the time at which events occur over Greenwich, England (0 degrees longitude). Since almost all of ASTRONOMY's readers live in North America, it makes sense to use the time familiar to them. It's also a lot easier to convert Eastern Time for the rest of the North American time zones; often, an event taking place under Universal Time occurs on the day following Eastern Time. Use of the latter helps reduce confusion.

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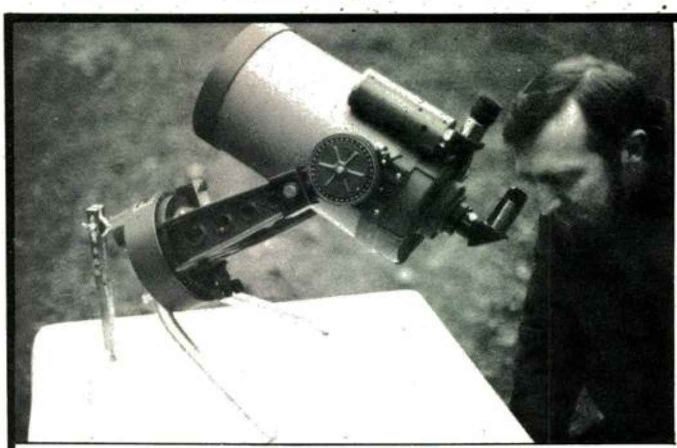

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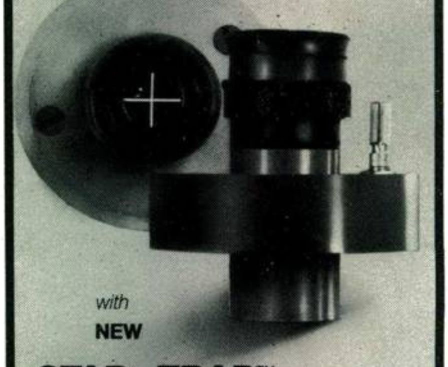

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STAR DOME

APRIL

by James Mullaney and Henry J. Phillips

Warm spring evenings entice fair-weather astronomers outdoors after a winter spent huddled near the radiator. Even after they pluck up enough courage to venture outside, some of the more timid souls may want to scurry right back into the house once they see the April constellations: bears, lions, a dragon and a sea monster! Experienced observers know better, but might they find themselves repressing a chill at the sight of a sky full of carnivorous beasts?

We smile today at the thought of anyone being frightened by the animals pictured in the stars. The ancients, however, were serious when they identified the constellations, and they never placed anything in the sky without a reason. Many of the human figures we know by Greek names were originally intended to represent the important occupations of past ages — the hunter (Orion), the archer (Sagittarius), the farmer (Bootes), and even rulers (Cepheus and Cassiopeia). Similarly, the animals in the sky were the ones that the ancients lived with: barnyard fowl, domesticated animals, and the wild beasts that preyed on both.

Leo the lion is one of the latter. Lions were fairly common animals in the regions where the earliest civilizations thrived, and we can safely assume that an angry lion was every bit as dangerous to our ancestors as it is to us now.

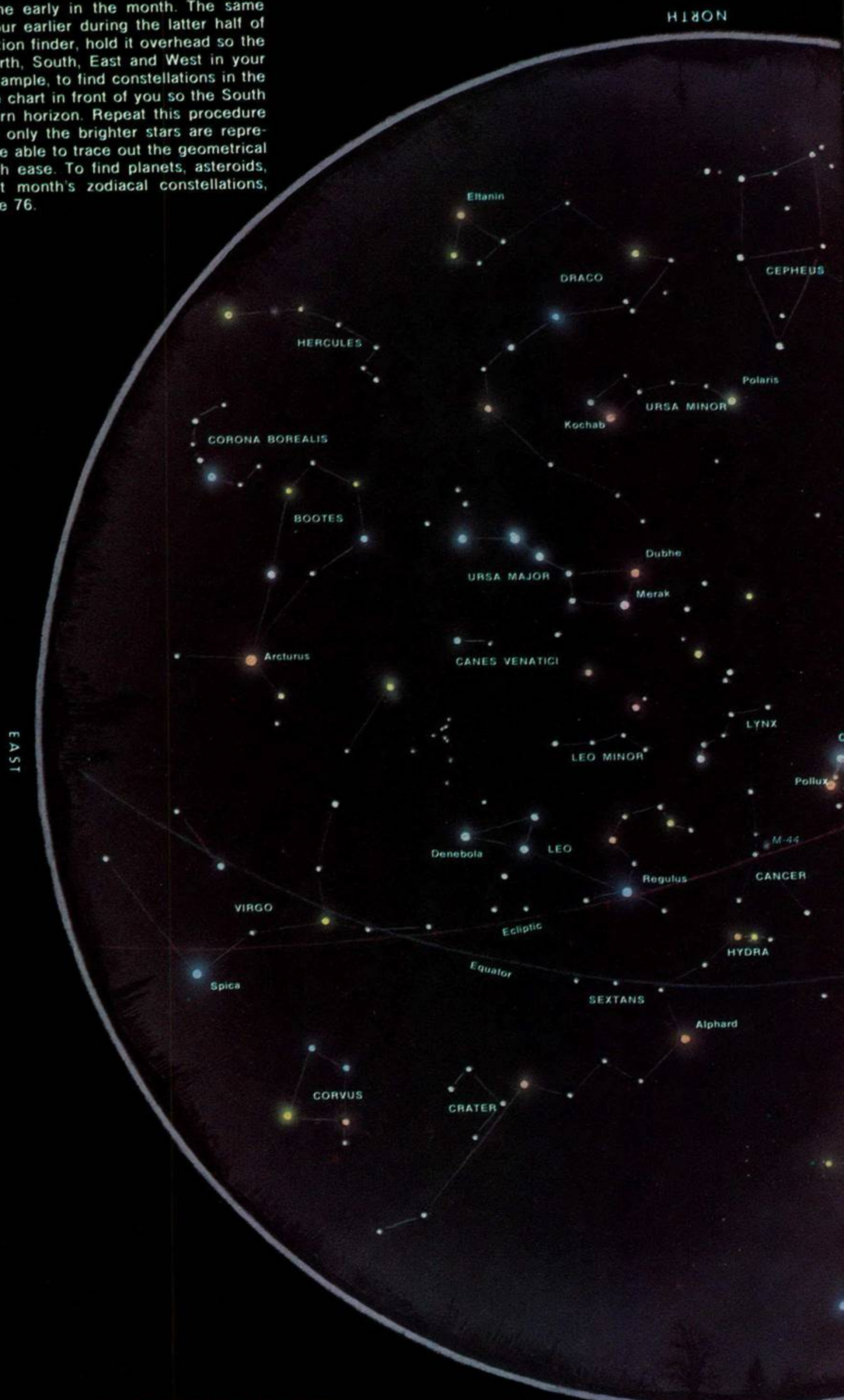
Since earliest times, Leo has been closely identified with the sun. The summer solstice was located in the constellation 5,000 years ago, when Leo was higher in the sky than it is at present. It was, in fact, the farthest north of the Zodiacal constellations, and assumed great importance with early cultures. One explanation says that the reason a lion is portrayed here was the sun's presence in Leo during Egyptian midsummer, when the Nile river overflowed its banks and lions came to cool off in the water. This picturesque idea is, unfortunately, no more than the product of a rather overactive imagination; but it is true that the Egyptians held the stars of Leo in high esteem. The annual flooding of the Nile was the most important event for the Egyptian civilization, and the sun's presence in Leo brought the lion great renown.

The lion's title of "king of beasts" is probably an offshoot of this close association with the sun. Both the animal and the constellation have always had royal connotations: Leo's brightest star, Regulus, was one of the four royal stars that ruled the heavens in Persian astronomy (the others were Antares, Fomalhaut and Aldebaran). Regulus received its present name from Copernicus (a diminutive of the Latin word "rex" meaning king). The star was given similar names by other people; for instance, it was called Magha or mighty in India, and the Persians knew it as Miyan, meaning the central one. Regulus is also sometimes called Cor Leonis, or the lion's heart; this was the meaning of its Arabic name, Al Kalb al Asad.

In one sense, Regulus' prominence in past ages may be surprising, because at magnitude 1.36, it is the faintest of all our first magnitude stars — although it is actually brighter than it seems, for its distance is 84 light-years. Blue in color, Regulus is on the meridian during the evening hours of April— located at the base of the sickle, Leo's distinctive asterism. The sickle (or backward question mark, if you prefer) is made up of six stars, with Regulus situated almost exactly on the ecliptic; the star is sometimes occulted by the moon. The sickle forms the lion's mane and forepaws, while a right triangle a short distance east represents the animal's hindquarters. The second magnitude star Denebola stands for the lion's tail , which is what the name Denebola means in Arabic. All in all, Leo is probably the most impressive of the spring constellations; it certainly has the most characteristic pattern of stars.

The other lion in the April sky is apparently no more than a cub. Leo Minor, located just north of its larger companion, contains no bright stars

This Star Dome rendering approximates the sky as it appears at about 8 p.m. Local Standard Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page 76.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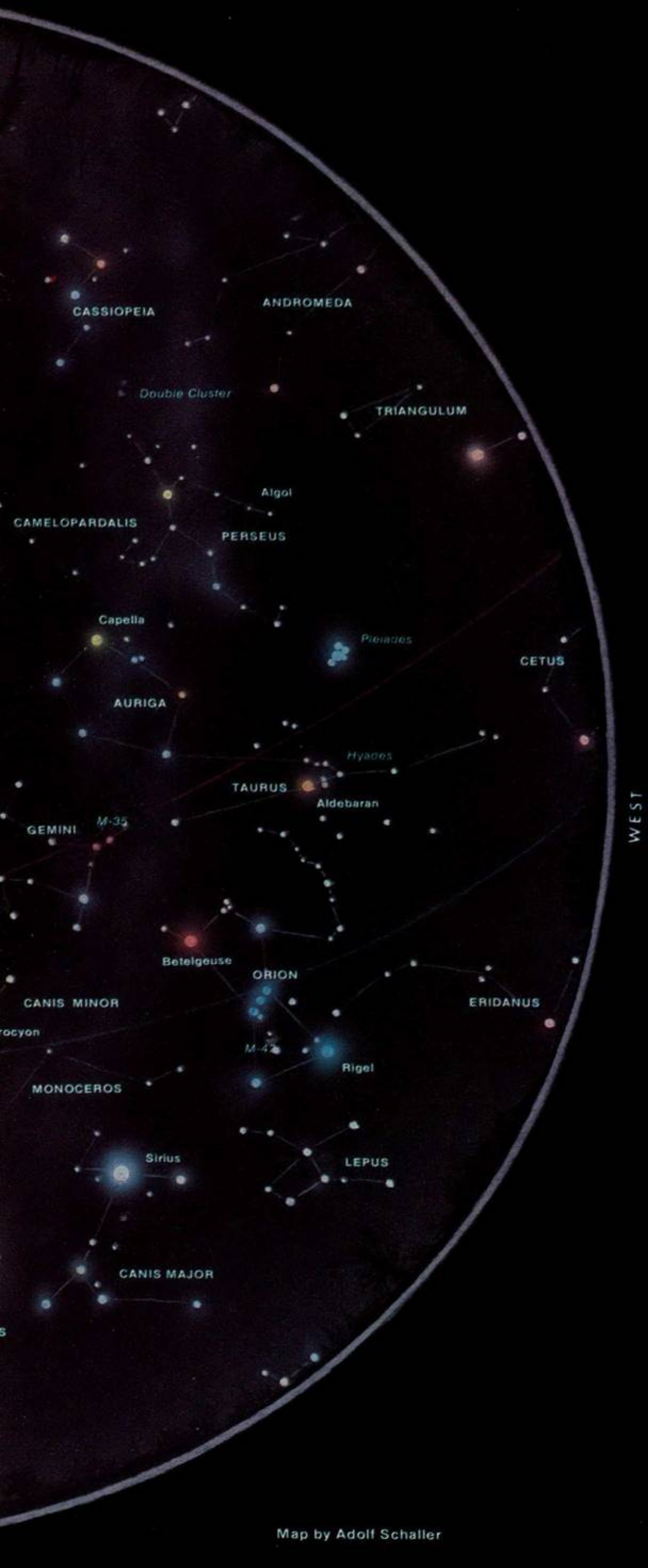
Map Centered on 40° North Latitude



Map by Adolf Schaller

and is quite uninteresting to the naked eye, although many galaxies can be found within its borders.

Southwest of Leo in an empty region of the sky shines a solitary second magnitude star. This is Alphard, the "lonely one" of the Arabs, and the brightest star in the constellation Hydra. It takes its name from its isolated position; there are no stars near it that are as bright. Its "loneliness" may even make it seem more luminous than it actually is, but Hydra contains very few bright stars and we should not begrudge it this one. Like Regulus, Alphard is also known as the "heart" of its animal: The star's alternate name is Cor Hydrae.

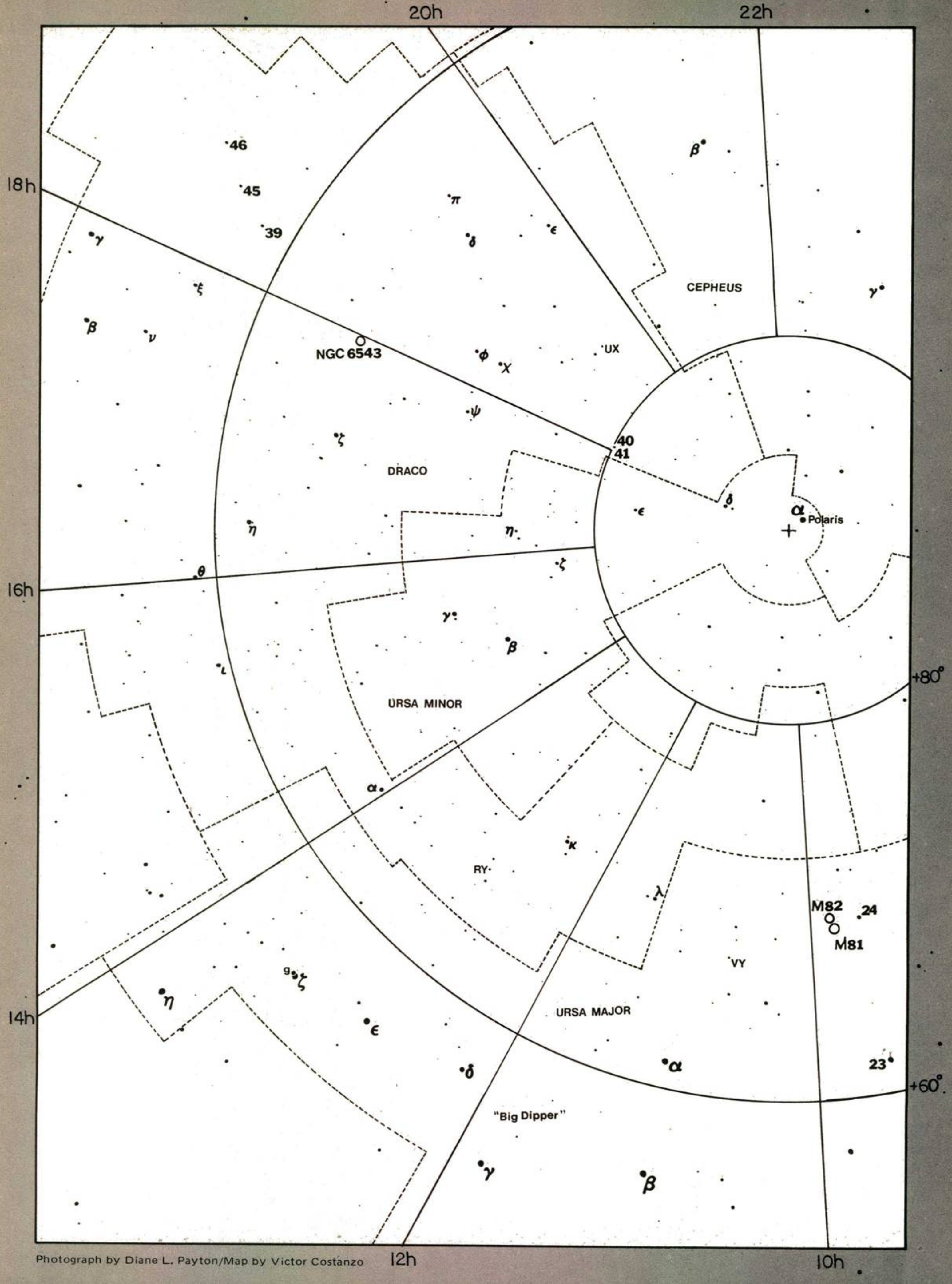
Hydra itself sprawls all the way across the spring sky, stretching from Canis Minor at its western end to Libra in the east. Up until about the 10th century A.D. it was not as long, but ended in the vicinity of the small group Crater, which today is usually shown balanced on Hydra's back. The constellation has always been a snake of some kind: sometimes a viper, sometimes a dragon, and — in one star catalog of the 18th century — a sea serpent. This last may be the closest realization of Hydra's original character, for the Greek word "hydros" means water. The Chaldeans had several star figures representing Tiamat, the gigantic dragon that nearly destroyed the world; Hydra was one of these.

Another dragon can be found much farther north. We know it today as *the* dragon — Draco, one of the northern circumpolar constellations, much brighter and more prominent than its cousin to the south. It is moving toward the meridian on April evenings, and will be highest during the evening hours in early summer.

One of the fourth magnitude stars in Draco's tail was once far more prominent than it is today. Draw a line between Mizar, the double star in the Big Dipper's handle, and the bowl of the Little Dipper. Midway along this line is Thuban — Alpha Draconis — a star which once marked the north celestial pole. About 2750 B.C., Thuban was less than 10 minutes of arc from the north pole, and could be seen by day and night from the central burial chamber of the Great Pyramid of Cheops in Egypt. A long shaft, sunk from the outside of the pyramid to this inner vault, was directed toward the pole. This design was almost certainly intentional; other, smaller pyramids have similar shafts.

When Thuban was the pole star, Ursa Major and Ursa Minor were situated on either side of it, and they swung closer around the celestial pole than they do today. The stars of the Big Dipper were then circumpolar from a much larger portion of the globe. Today, the Dipper scrapes the horizon in the autumn, but 5,000 years ago it was less than half its present distance from the north pole.

The Big Dipper has been, in all times and to all peoples, the best known of the constellations. Today, it is only part of the larger group Ursa Major, the great bear. But for the greater part of its history,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"Big Dipper"
γ
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Photograph by Diane L. Payton/Map by Victor Costanzo the Big Dipper has stood alone—as well it might, being such a bright and distinctive group. The name Big Dipper, however, is only of recent American origin, and is probably the newest name the figure has received. In England it is known as the plow (or, to use the British spelling, plough), or as Charles' Wain. The "Charles" in this title is usually supposed to refer to one of the 17th century English kings, but the name is actually much older. Shakespeare referred to the group by this name, and its use can be traced back to medieval Saxon peasants. The "wain" is an old English word for wagon or cart, and the original Charles of the title was Charlemagne. The resemblance to a cart trundling around the pole is faint, and more than a bit comical.

This area of the sky was also known as the home of the legendary King Arthur. The Welsh word for bear is "arth", and the stars of the Big Dipper have been portrayed as a bear by many different races–even those as widely separated as the Welsh, the Greeks, and the North American Indians. Experts have guessed that this similarity was brought about by a long-extinct, common ancestor of all these races–an ancestor that gave the bear its name. This speculation is unprovable at present, but the fact that the Big Dipper has no resemblance at all to a bear adds to the mystery.

The Arabs knew this constellation not as the Great Bear, but the Great *Bier.* The Dipper's bowl represented the coffin of a hero, and the three stars of the handle were the dead man's daughters following the bier in mourning. A similar, but more horrifying, story is told by the Persians. In this account, the mourners are the children of the hero Al Na'ash, who was murdered by the pole star. The children march continually around the pole, hoping eventually to exact revenge for their father's death. One of the daughters (Mizar) carries her newborn infant in her arms.

Other people told still different stories. The Finns thought the seven stars of the Dipper were seven young girls skilled in spinning and weaving. The ancient Germans called it the chariot of their chief god, Wotan. And many people simply knew it as the Seven Stars–certainly an appropriate title, and far more suited to the Dipper than to the Pleiades, another group with a similar name.

The Little Dipper also contains seven stars, arranged in a pattern rather similar to that of the larger Dipper nearby, so it's not surprising that many of the stories attached to the Big Dipper are simply repeated on a somewhat smaller scale for Ursa Minor. Thus we have a lesser bear, a smaller wagon, and mourners following the coffin of a less important hero.

But as the north pole drew away from Thuban and entered Ursa Minor, the constellation began to take on greater prominence. Mariners learned to steer their ships by the stars of Ursa Minor, rather than the brighter stars of Ursa Major, because the former gave truer direction. By the time Ptolemy wrote his famous star catalog, the **Almagest,** in the second century A.D., Polaris was close enough to the pole to be considered the north pole star; it has been drawing closer to true north ever since.

Today, the two bright stars in the Little Dipper's bowl are called the Guardians of the Pole, protecting our current pole star from would-be intruders. The derivation of the name "Polaris" for the north star is obvious. It now stands nearly motionless, circled slowly by the entire star dome.

Close-up on the North Polar Region

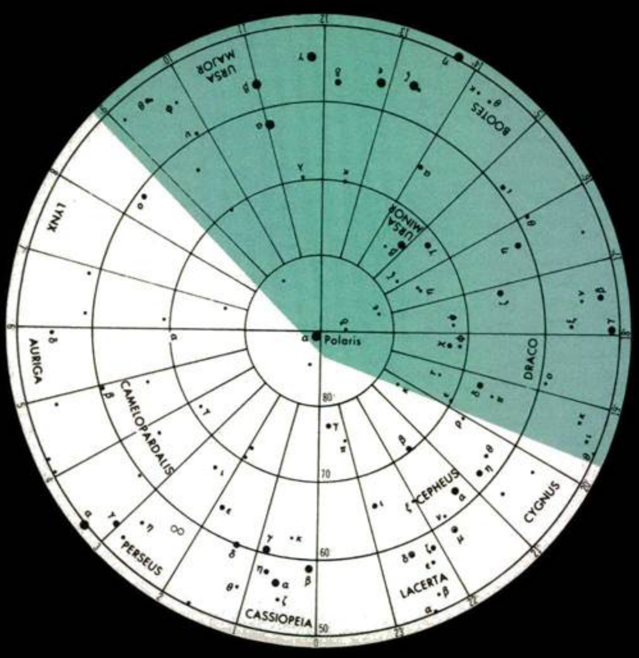
The expanse of sky surrounding the north celestial pole may seem a stellar desert to the unaided eye. As a result, most astronomy enthusiasts give little attention to this area in their nightly explorations of the heavens. Yet, as our table of selected objects hints, the north polar region holds many buried treasures for users of small telescopes.

The north circumpolar stars also have considerable practical value; persons familiar with the star patterns can determine direction, time and season at a glance. Everyone knows that Polaris is located almost exactly on the north celestial pole, or north on the compass. As such, it is probably the most useful star in the night sky.

We can also tell the season of the year from these stars. During the early evening hours in spring, the Big Dipper is placed high in the northern sky above the pole. In summer it is to the left, or west, of Polaris. In autumn, look for the Dipper near the northern horizon, and in winter to the right (east) of the pole.

To determine the approximate time of night, note that Ursa Major circles the pole once every 24 hours–an apparent motion caused by the rotation of Earth on its axis. We can regard an imaginary line, connecting Polaris with the pointer stars (Alpha and Beta) in the bowl of the Big Dipper, as the hour hand of a celestial clock. Compare the position of this stellar hour hand with actual watch time at each season. With some practice, you can tell the time of night to within an hour, needing no timepiece but the stars themselves. There is, however, one important difference between our sky clock and manmade ones; as we face north, the celestial hour hand turns counterclockwise.

The polar stars provide another useful service: They help us determine the quality of sky conditions. We can monitor transparency (atmospheric clarity) by checking the visibility of the stars in the bowl of the Little Dipper (Ursa Minor). The magnitude sequence contains second (Beta), third (Gamma), fourth (Zeta), and fifth magnitude stars (Eta), and it's an ideal index of sky clarity. If you can trace the entire Little Dipper with the naked eye, trans-



Map from **Guideposts to the Stars**; reprinted permission of MacMillan Publishing Co., ©1972 by Leslie C. Peltier.

Stars in each constellation are indicated, in order of brightness, with the Greek Alphabet.

α	**Alpha**	η	**Eta**	ν	**Nu**	τ	**Tau**
β	**Beta**	θ	**Theta**	ξ	**Xi**	υ	**Upsilon**
γ	**Gamma**	ι	**Iota**	ο	**Omicron**	φ	**Phi**
δ	**Delta**	κ	**Kappa**	π	**Pi**	χ	**Chi**
ε	**Epsilon**	λ	**Lambda**	ρ	**Rho**	ψ	**Psi**
ζ	**Zeta**	μ	**Mu**	σ	**Sigma**	ω	**Omega**

Table of Selected Objects — North Polar Region

Object	Type	Mag.	Size/Sep.	R.A. (1950)	Dec.
URSA MINOR					
•α(Polaris)	★2	2.1, 9.0	18"	01^h49^m	+89°02'
URSA MAJOR					
23	★2	3.8, 9.3	23"	09^h28^m	+63°17'
•M-81	Sp	7.9	21'x10'	09^h52^m	+69°18'
•M-82	Ir	8.8	9'x4'	09^h52^m	+69°56'
VY	V:ir	6.0–6.6	—	10^h42^m	+67°40'
DRACO					
RY	$V{:}172.5^d$	5.6–8.0	—	12^h54^m	+66°16'
ψ (Psi)	★2	4.9, 6.1	30"	17^h43^m	+72°11'
•NGC-6543	PN	8.8	22"	17^h59^m	+66°38'
40/41	★2	5.8, 6.2	19"	18^h04^m	+80°00'
UX	$V{:}168^d$	6.2–6.9	—	19^h23^m	+76°28'
ε (Epsilon)	★2	4.0, 7.1	3"	19^h48^m	+70°08'

• Detailed in Eyepiece Impressions

★ 2, 3, 4=Double/Multiple Star
PN=Planetary Nebula
Sp=Spiral Galaxy
Ir=Irregular Galaxy
Mag.=Magnitude
Sep.=Separation

$V{:}\#^{dhm}$ =Variable Star, Period–days, hours, minutes

parency is excellent—by modern standards—for those living near large cities.

Finally, the constellations near the pole serve as valuable, ever-present yardsticks for estimating angular distances in the sky. For example, the span between Dubhe (Alpha Ursae Majoris) and Polaris is almost 30 degrees; that between Dubhe and Merak —the pointer stars in the Big Dipper—is five degrees. From Gamma to Beta (across the bottom of the Big Dipper's bowl) measures seven degrees, while the distance between Delta and Alpha (across the top of the bowl) is 10 degrees. Try mentally placing the moon, at ½ degree apparent diameter, between some of these pairs of stars. It seems impossible, and yet it's true, that 10 full moons could fit between Dubhe and Merak!

Eyepiece Impressions

Before we begin our examination of deep sky objects around the pole, we offer a suggestion to those readers whose instruments are equipped with equatorial mounts. It's awkward, to say the least, to sweep for celestial prey in the north polar region with a telescope so mounted. Unless you need your clock drive for extended viewing or time exposure photography, point the polar axis of your instrument to the east or west at right angles to Polaris. You'll have a much more "natural" feeling as you search for objects.

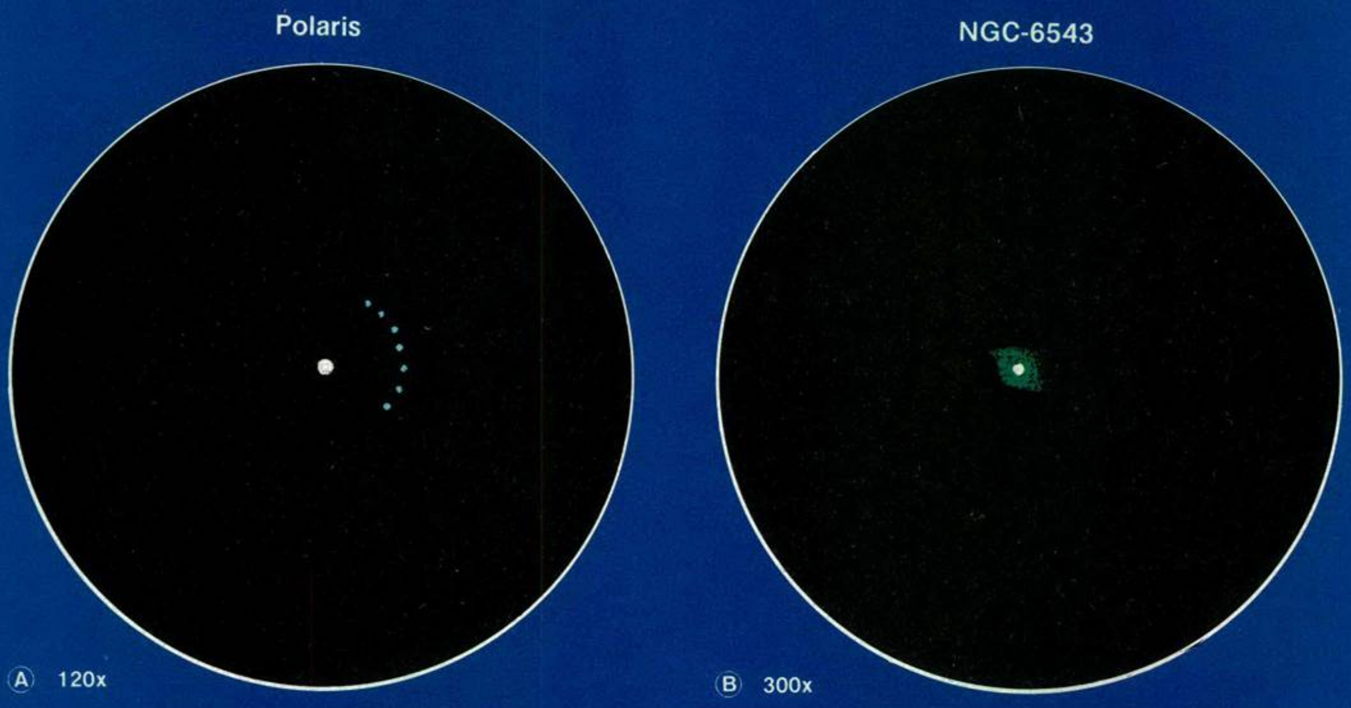
Polaris

As valuable to astronomy as Polaris is, it is rarely considered a worthy telescopic object. But its proximity to the north celestial pole makes Polaris the most unique double star in the entire sky.

At present, Polaris is situated less than a degree from the actual pole. Due to the slow effects of precession, this gap will continue to close until the year 2100 A.D., when the star will be just 26 minutes of arc from true north. Polaris will then gradually move off, eventually giving way to another pole star in the remote future as the 26,000 year precessional cycle proceeds.

This neglected double star consists of the second magnitude, yellowish-white primary, and a ninth magnitude blue-white companion some 18 seconds of arc distant. A three inch refractor or four inch reflector at 45 power shows the companion nicely, with the pair forming a pleasing magnitude contrast. Larger apertures, with their greater light collecting power, enhance the visibility of the faint star.

Most visual double stars have periods measured in decades or centuries. What makes Polaris so unusual for the visual observer is the complete orbital revolution that the companion appears to make about the primary every 24 hours! This apparent motion is actually an illusion produced by Earth's



Polaris, the north star, is actually a double; the separation of the primary from its ninth magnitude companion is 18 seconds of arc. The companion appears to orbit Polaris every 24 hours — an illusion produced by the pair's nearness to the pole. Diagram A demonstrates this apparent motion at one hour intervals. The view is through a four inch Unitron refractor with a field of 1/2 degree. Diagram B depicts another "polar" object, the planetary nebula NGC-6543, which is situated almost exactly at the north ecliptic pole. A 10 inch Cave Astrola reflector shows the nebula's blue-green disk and tiny central star; the field is about 10 minutes of arc. Galaxies M-81 and M-82 are visible in the same one degree field through a six inch Edmund reflector. The two galaxies are the farthest north of all the Messier objects. M-81, at the top of diagram C, is an obvious spiral, while M-82 has a more elongated shape. Drawings by James Mullaney.

rotation and Polaris' position so near the pole. This "orbital" motion is shown over a six hour period in our drawing. Even though the companion is not making a true orbit, the effect seems very real in the telescope when checked from hour to hour.

In addition to the visual pair, the primary is also a long-period spectroscopic binary, and astronomers suspect other members belong to the system. Polaris is also a Cepheid variable star with a small range — about 1/10 magnitude — and a period of four days. Although it is only second magnitude in our sky, this stellar beacon is a yellow supergiant more than 2,500 times as luminous as the sun. Indeed, at Polaris's distance of 680 light-years, our own sun would be quite invisible to the unaided eye.

NGC-6543

Nestled within the first bend of Draco the dragon's body lies one of the brightest planetary nebulae in the heavens. This is NGC-6543, situated almost exactly at the north pole of the ecliptic (the point around which all precessional motion revolves over the centuries).

Like most members of its class, this object requires careful sweeping — preferably at medium magnifications — to locate, even when its position is known, due to its small angular size. A line from second magnitude Gamma (γ) through fourth magnitude Xi (ξ) Draconis roughly points it out. A more precise fix is made by finding the midpoint of a line joining the third magnitude stars Delta (δ) and Zeta (ζ) Draconis.

Although visible in a three inch refractor at 70 power, the nebula is a much more striking sight in eight inch and larger instruments. Its vivid blue-green disk, catalogued at magnitude 8.8 and 22 seconds of arc in diameter, contains an 11th magnitude central star. Ten to twelve inch telescopes at high power reveal complex internal detail in the form of intersecting rings of luminous material. The outer edge of the nebula has a distinct asymmetrical outline, rather resembling a cosmic snail.

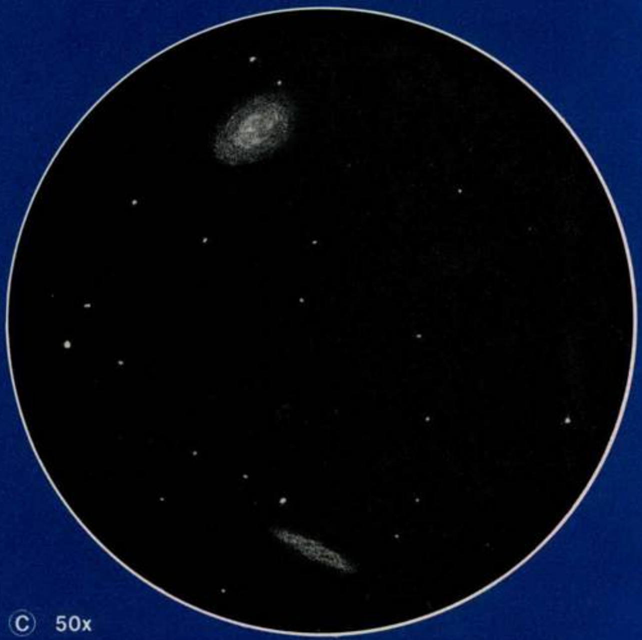
Barns, using his homemade 10 inch reflector in clear California skies, describes NGC-6543 briefly as: "Planetary nebula. Diameter 35 seconds. Luminous blue. Magnification discloses star center."

Webb elaborates: "Very curious...I found very luminous disk, much like a considerable star out of focus. Herschel 35 seconds diameter; I saw but 15 or 20 seconds with 3.7 inch (refractor)."

As we can tell from these comments, the apparent diameter of a nebula like NGC-6543 depends to some extent on the size of telescope used. For those having six inch and larger instruments, an interesting exercise is to observe this object at full aperture, then mask down in one inch steps, estimating the size of the diameter after each masking.

NGC-6543 was the first planetary nebula to reveal its gaseous nature to the probing eye of the spectroscope in 1864. Being circumpolar in our latitude, it is visible throughout the year, but is best seen when at "upper culmination" on the meridian

M-81 and M-82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high above the pole. Its distance from Earth is about 3,500 light-years.

M-81 and M-82

One of the finest and brightest pairs of galaxies located anywhere in the sky lurks just beyond the bowl of the Big Dipper, within easy reach of small telescopes or even large aperture binoculars. This is the galactic duo known as M-81 and M-82. To find these galaxies, draw a line from Gamma (γ) to Alpha (α) Ursae Majoris across the bowl of the Dipper and prolong this line its own length. Sweeping with a low power wide field eyepiece on a dark night will reveal these distant star cities, just east of fourth magnitude 24 Ursae Majoris.

One of these patches of light is an eighth magnitude egg shaped glow extending some 21 by 10 minutes of arc. This is the often-pictured, graceful spiral galaxy M-81. Approximately ½ degree north of M-81 is M-82, a narrow curved ray of light, about nine by four minutes of arc in size, and nearly a magnitude fainter than its neighbor.

Even a 2.4 inch refractor at 30 power will show the pair nicely through a sprinkling of distant stars. Most observers see M-81 as more circular, and M-82 as more elongated, than the published dimensions suggest. Angular sizes of 16 by 10 minutes for M-81 and 10 by 2 minutes for M-82 more nearly match their visual appearance.

M-81's bright core and fainter disk are easily visible in 8 and 10 inch reflectors, at 80 to 160 power. The beautiful spiral arms seen in observatory photographs appear as a ghostly halo of light surrounding the nucleus and disk. In moments of superfine seeing, 10 to 12 inch instruments show tantalizing hints of the actual arms winding about the galaxy's center.

M-82 has a spindle shape; with careful attention, dark rifts of obscuring dust and gas can be seen crossing the galaxy diagonally, even in four to six inch telescopes.

Although M-82's appearance gives the impression that we see it edge-on, its actual classification is "peculiar". Time exposure photos show a mysterious eruption emanating from the nucleus at right angles to the plane of the galaxy, and some scientists have guessed that the entire galaxy is suffering a titanic explosion.

Barns describes this pair of galaxies as "Two nebulae. Argent (silver), 30 minutes apart. Unlike in size, structure and glow. Worth search." This last comment is truly an understatement, for M-81 and M-82 — seen together in a wide field eyepiece — are a magnificent sight.

A more detailed description of this pair is given by Webb: "Two nebulae ½ degree apart; M-81 bright, with vivid nucleus, finely grouped with small stars, two of which are projected upon the haze...M-82 (Bode's nebula), curious narrow curved ray." Webb also tells us that d'Arrest (another noted observer of the past) saw two nuclei in M-82, and that it seemed to sparkle as if resolvable, which M-81 did not. A number of faint foreground stars superimposed against M-82's image might account for the sparkling effect.

Try observing the changing appearance of these galaxies during an auroral display. The different colored forms act like selective filters through which the galaxies' light must pass before reaching the telescope, and their visual appearance undergoes some curious effects.

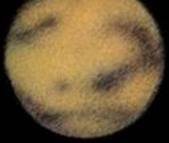
As with NGC-6543, M-81 and M-82 are visible throughout the entire year, but are most easily viewed during the spring, when they are high above the pole in the early evening hours. Both galaxies are at the same distance from us—6.5 million light-years—and may very well form a physical system bound together by mutual gravitation, like a colossal double star hung in the void of intergalactic space. The are included in a vast gathering of island universes scattered throughout Ursa Major. In the bowl of the Big Dipper alone, more than a million galaxies can be photographed with the 200 inch telescope at Palomar!

In observing objects like M-81 and M-82, much of the fascination lies not in the visual appearance of the blur of light in the eyepiece, but in what that faint glow represents. Here, the realization that we are viewing vast, distant systems, containing billions of stars, can take the breath away. But there is another side to the picture. As one writer has put it: "To some, the contemplation of the overwhelming vastness of stellar systems, of universes—of systems of universes — is terrifying beyond measure. This should not be. Let him raise his head...in proud amazement at the greater wonder: that he can sieze and hold this mighty immensity in the grasp of his tiny brain."

Planet Finder

Ⓒ **Ceres**

April	1	15
R.A.	4h56m	5h17m
Dec.	+25°11'	+26°00'
Mag.	+7.7	+8.0



Ⓐ **Mercury**

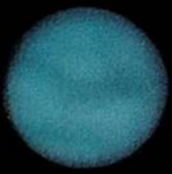
April	1
R.A.	0h41m
Dec.	+3°08'
Mag.	-1.7

Ⓑ **Mercury**

April	15
R.A.	2h32m
Dec.	+16°29'
Mag.	-0.8

Ⓜ **Mars**

April	1	15
R.A.	6h29m	7h00m
Dec.	+25°25'	+24°42'
Mag.	+1.1	+1.2



Ⓝ **Neptune**

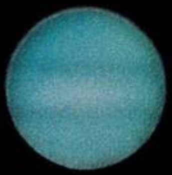
April	15
R.A.	16h50m
Dec.	-20°54'
Mag.	+7.7

SUN

The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

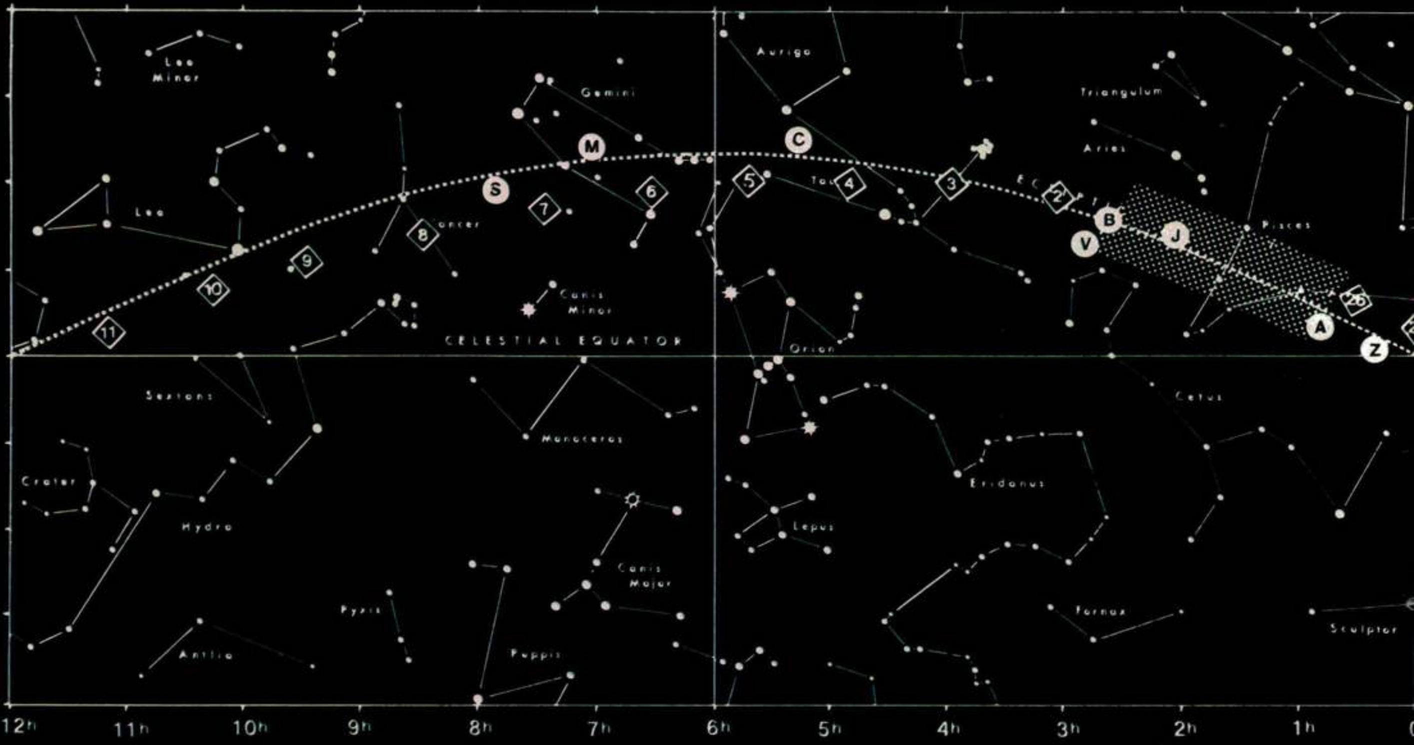
Ⓢ **Saturn**

April	1	15
R.A.	7h52m	7h54m
Dec.	+21°19'	+21°16'
Mag.	+0.3	+0.3



Ⓤ **Uranus**

April	15
R.A.	14h13m
Dec.	-12°52'
Mag.	+5.7


Leo Minor
Gemini
Leo
M
S
6
7
8
Cancer
9
10
11
Canis Minor
CELESTIAL EQUATOR
Sextans
Monoceros
Crater
Hydra
Canis Major
Pyxis
Antlia
Puppis
Auriga
Triangulum
Aries
C
5
Taurus
4
3
EC
2
B
V
J
Pisces
26
A
Z
Orion
Cetus
Eridanus
Lepus
Fornax
Sculptor
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec. = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag. = magnitude, a

April 1976

Ⓥ Vesta

April	1	15
R.A.	2h16m	2h39m
Dec.	+8°47'	+10°58'
Mag.	+8.2	+8.2

Ⓟ Pluto

April	15
R.A.	13h03m
Dec.	+12°16'
Mag.	+14

Ⓙ Jupiter

April	1	15
R.A.	1h59m	2h11m
Dec.	+11°04'	+12°13'
Mag.	-1.6	-1.6

Ⓨ Venus

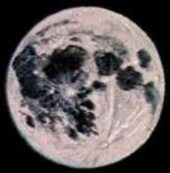
April	1
R.A.	23h33m
Dec.	-4°27'
Mag.	-3.3

Ⓩ Venus

April	15
R.A.	0h37m
Dec.	+2°19'
Mag.	-3.3

First Quarter

April 7

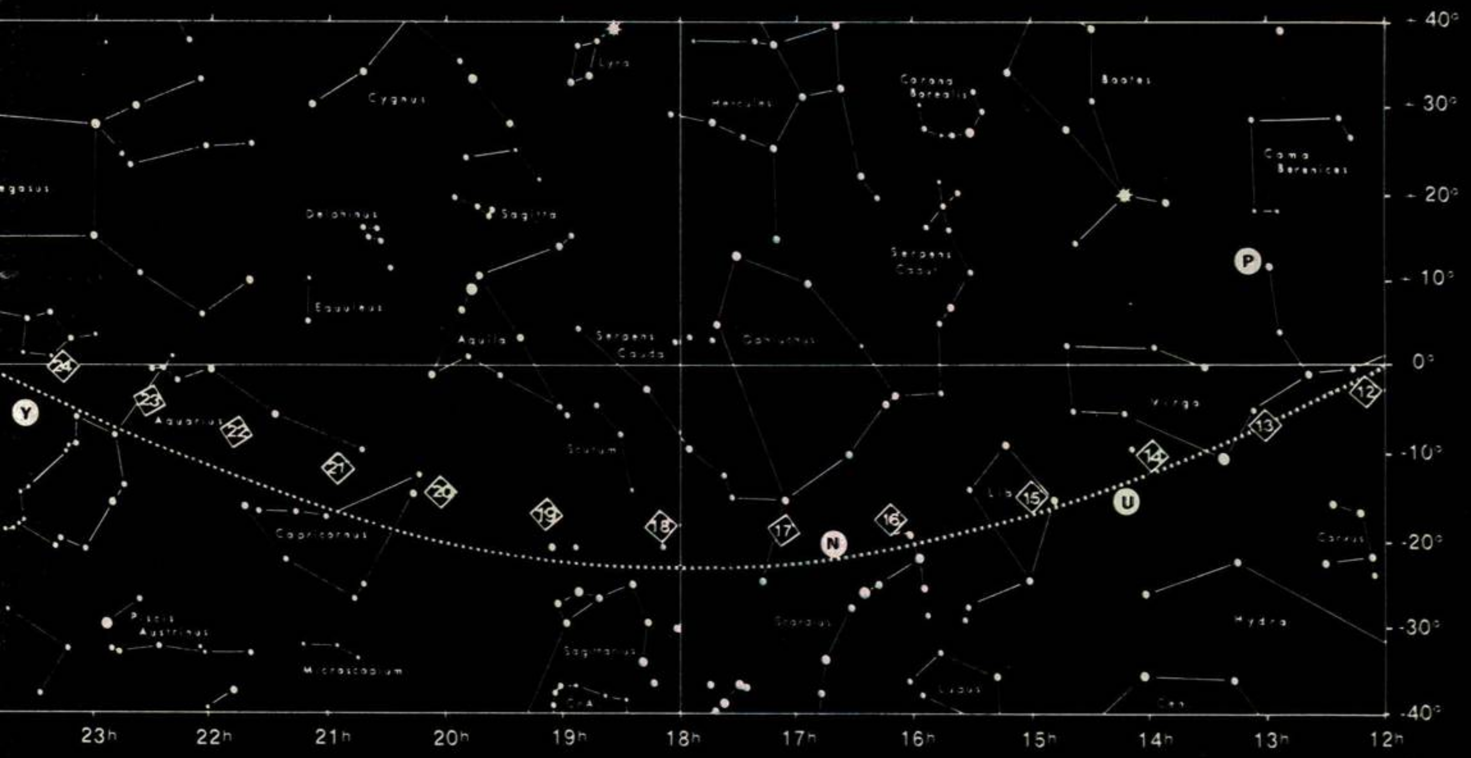


Full Moon

April 14

Last Quarter

April 21



+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h
egasus
Cygnus
Lyra
Hercules
Corona Borealis
Bootes
Coma Berenices
Delphinus
Sagitta
Equuleus
Serpens Caput
Aquila
Serpens Cauda
Ophiuchus
Virgo
Aquarius
Scutum
Libra
Capricornus
Corvus
Scorpius
Hydra
Piscis Austrinus
Microscopium
Sagittarius
Lupus
CrA
Cen
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24
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14
13
12

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.

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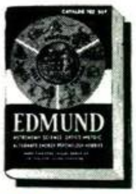

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We stepped up production as rapidly as we could—but remember, this is a precision, handcrafted instrument, individually built to our exacting standards, and individually guaranteed. In addition, our industry like most others has had to contend with shortages. At times, critical materials have just not been available. In spite of all efforts, order backlogs grew, and we have felt obliged to offer refunds to anyone who did not want to wait. (Very few accepted—which itself is significant.) Today our backlog has been brought down a great deal, though we must still reluctantly keep you waiting a while. Our apologies... but it is comforting to know that when your telescope arrives, it will be in every respect the easy-to-operate, outstanding performer you ordered—an RV-6 Dynascope.

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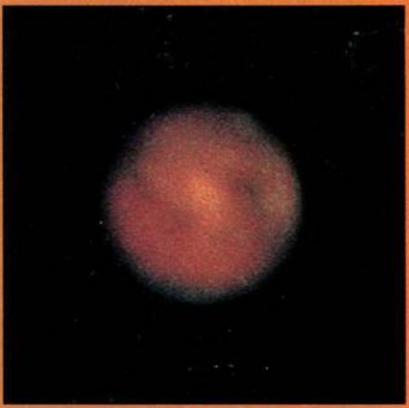
Great Nebula in Orion
Photo by Arnie Rosner

Rings of Saturn
Photo by Jim Matteson

Immediate Delivery — Since the introduction of the Celestron 8 six years ago, the demand for this instrument has always exceeded our production capacity and we have had to ask customers to wait for their orders. But now, with expanded production facilities and the introduction of more sophisticated testing techniques, we are able to offer off-the-shelf delivery of the Celestron 8 which routinely provides 1/40th-wave-r.m.s. image quality.

Optical Guarantee — We guarantee 1/10-wave-peak and 1/30-wave-r.m.s. image quality at the focal plane of the Celestron 8. This telescope is most often specified by educational institutes and is the most coveted by serious amateur astronomers. Its optical quality is limited only by modern glass materials and the most advanced testing techniques. For those who desire back-up documentation of these claims, we will send, on request, a list of the many colleges and universities that have selected the Celestron as a primary teaching instrument; and, for a small fee, we will provide you with a certified test report including laser interferograms documenting the optical quality of your serialized Celestron 8.



Martian Surface Features
Photo by Alan MacFarlane

Cloud Belts of Jupiter
Photo by Jim Matteson

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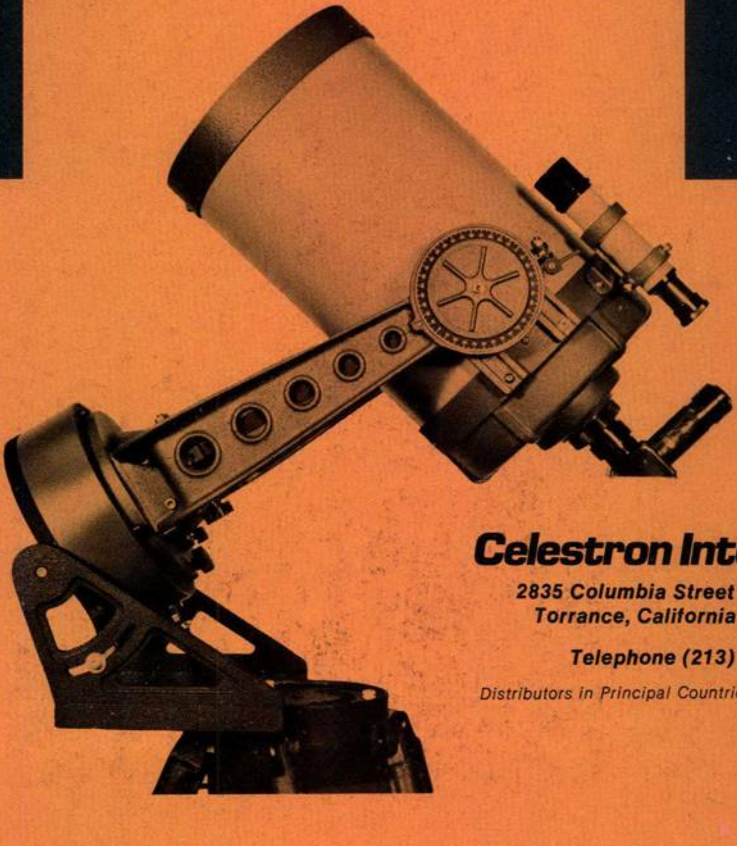

The Celestron 8, with which all photographs here were made, is available now from stock at the base price of $895.

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